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(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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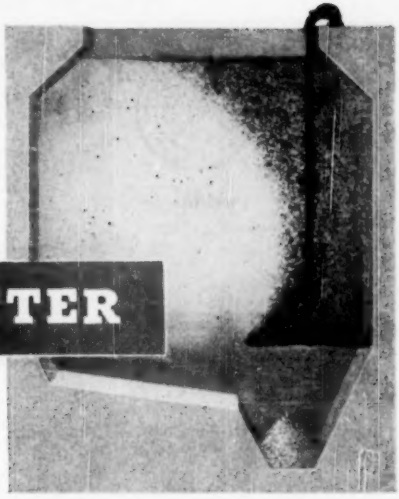

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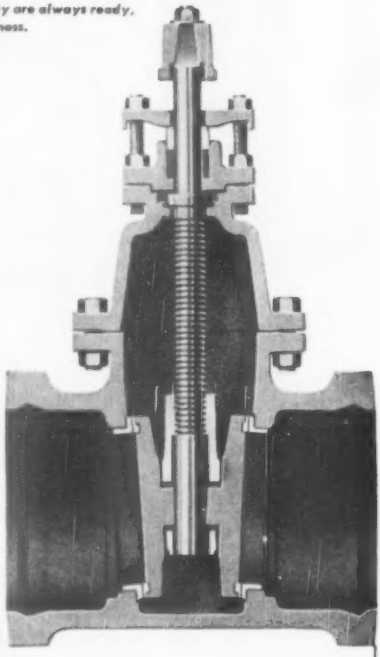

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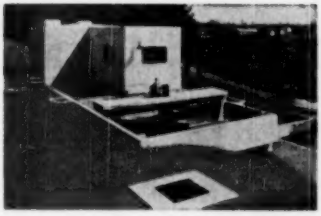

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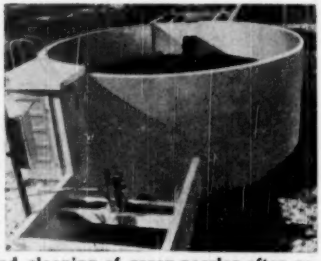

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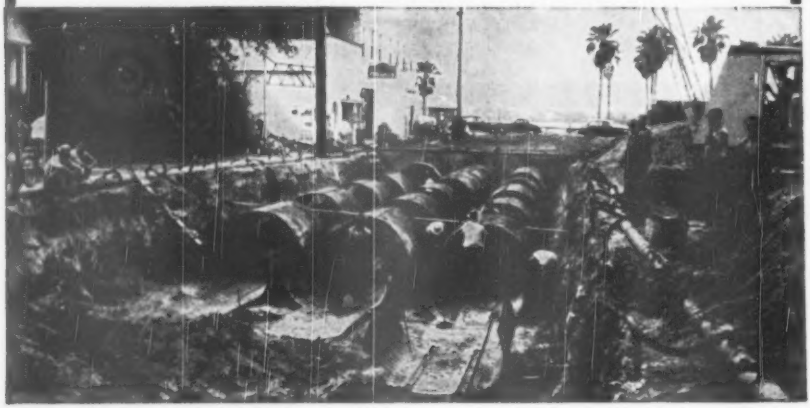

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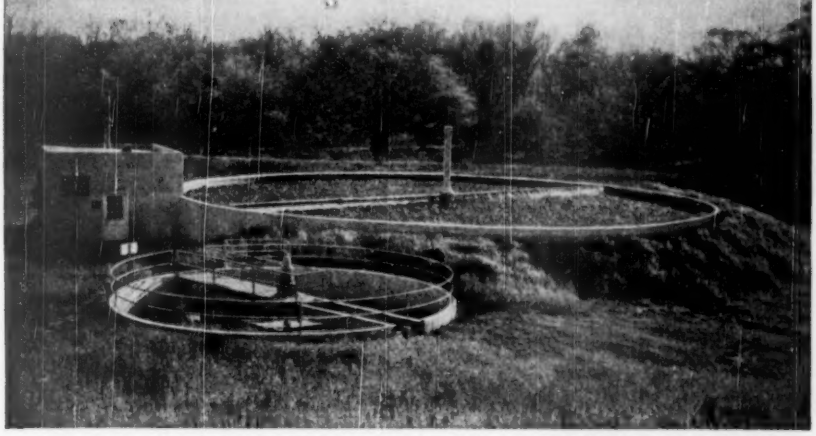

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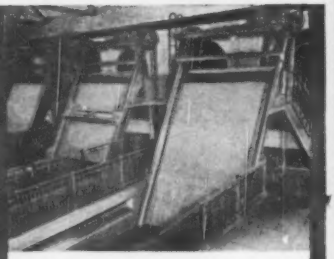

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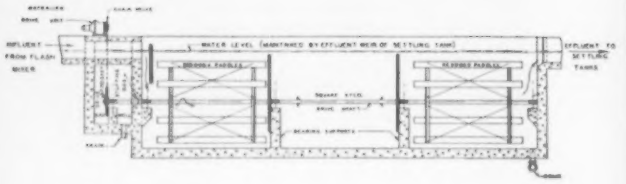

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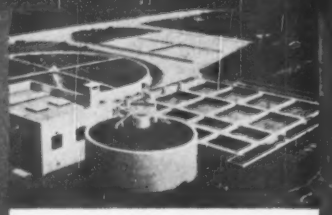

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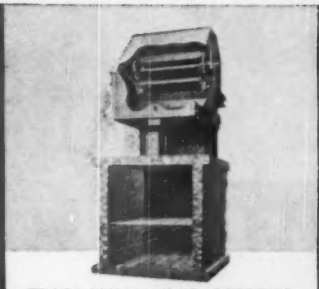

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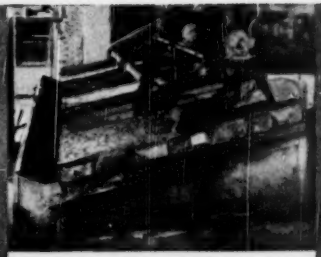

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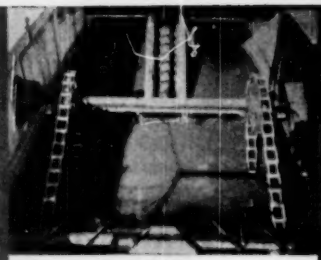

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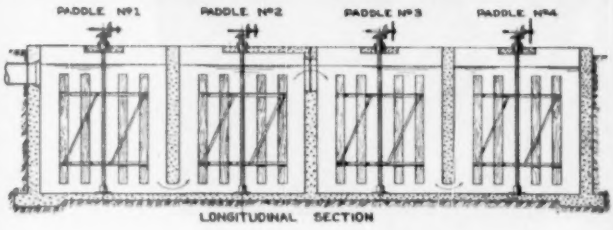

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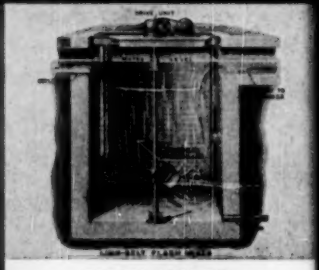

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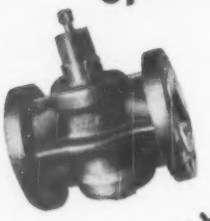

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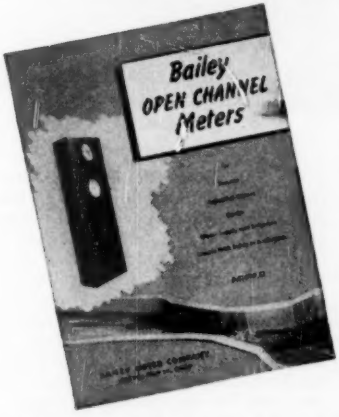

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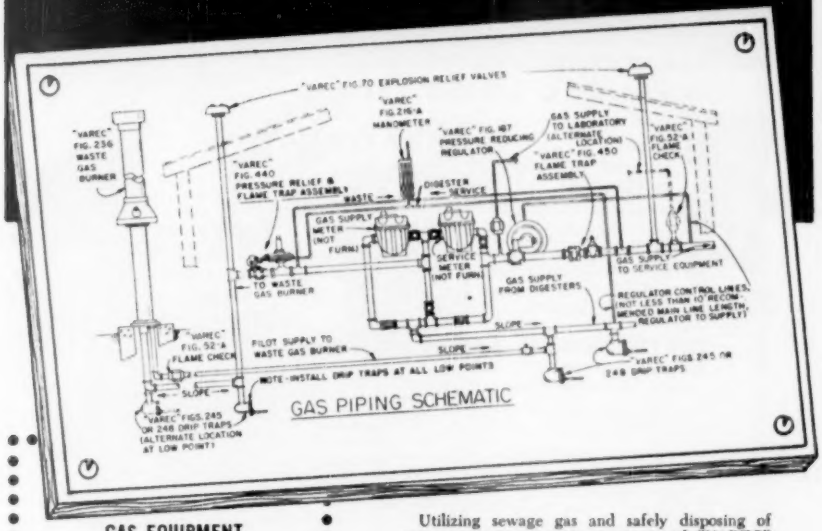
"VAREC" FIG. 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 107 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATION)
"VAREC" FIG. 52-B FLAME CHECK
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
WASTE
DIGESTER SERVICE
GAS SUPPLY METER (NOT FURN.)
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GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES NOT LESS THAN 10 RECOMMENDED MAIN LINE LENGTH. REGULATOR TO SUPPLY
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
SLOPE
"VAREC" FIGS. 245 OR 248 DRIP TRAPS
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
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GAS PIPING SCHEMATIC

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d. **EXPLOSION RELIEF VALVES**
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e. **WASTE GAS BURNER**
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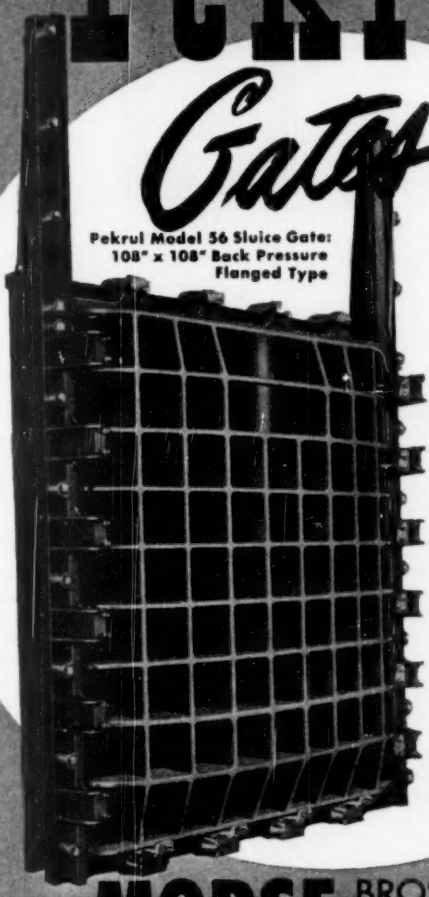

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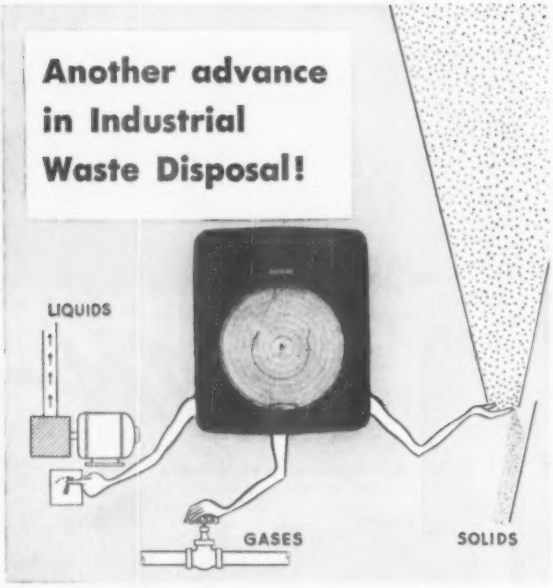

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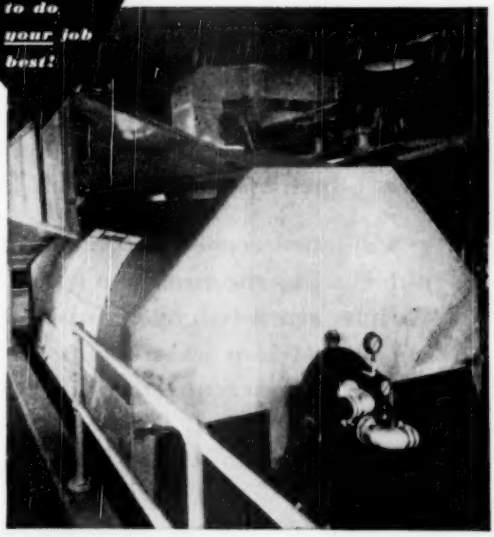

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 22 NOVEMBER, 1950 Number 11

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois

Herbert P. Orland, *Assistant Editor* Dr. F. W. Mohlman, *Advisory Editor*

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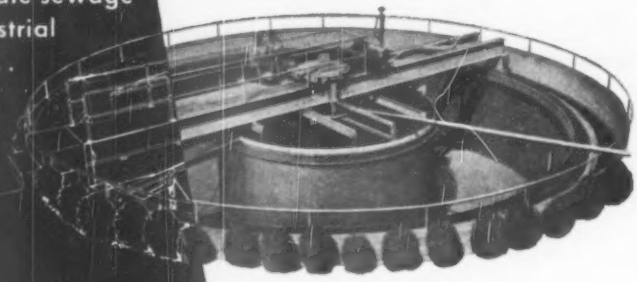
to preaerate sewage and industrial wastes . . .



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RESEARCH ENGINEERING EQUIPMENT

Sewage Works

SEWAGE DISPOSAL PROGRAM FOR CINCINNATI AND VICINITY *

I. GENERAL PLAN AND FEATURES OF LITTLE MIAMI PLANT

By Frank C. Tolles

Partner, Havens and Emerson, Consulting Engineers, Cleveland, Ohio

Development of the Cincinnati sewage works project has involved a number of diverse though interrelated activities. These include:

1. Bringing the electorate to appreciation of the need for bond issues for intercepting sewers and for studies and investigations.
2. Preparation of general plans for the whole city and of detailed plans for the Little Miami project.
3. Enactment of basic charges for sewage service and development of a financing program, which affected city and suburbs, with a continued campaign of education, which eventuated in joint support of measures for the treatment of sewage.
4. Adaptation of city plans to meet the objectives of the Ohio River Valley Water Sanitation Commission.
5. Extension of earlier surveys of industrial wastes into the writing of ordinance for regulation and for establishing surcharges on wastes of excess strengths.

These five steps represent continued and progressive attack upon the problem during a long period, but, also, they signalize the varieties of effort characterizing a problem such as has faced the city. The speaker is the freer to bring out these points in that they mark the interest and activity of city officials themselves in promoting a project that involved complexities of human and civic relationships.

General Plan

The plan itself is based on the situation of a metropolitan area with 20 mi. of river front, and extending inland to a maximum depth of about 14 mi. This area comprises the city itself and 21 other municipalities, together with county area, all aggregating 214 sq. mi., and all draining to the Ohio River through some 60 city-owned sewers.

Topographically, this area divides into four main drainage areas (see Figure 1). That of Mill Creek, which includes the central city, is the largest, the most populous, and contributes the greatest volume of industrial wastes. To the east is the watershed of the Little Miami River, largely residential, but with outlet which is not too far from water intakes. To the west are two smaller areas—Rapid Run and Muddy Creek—yet largely undeveloped. A better understanding of these areas comes from estimates of population and average sewage flow for the year 1960, thus:

Area	Population	Sewage (m.g.d.)
Mill Creek (central)	561,000	106
Little Miami (upstream)	132,000	23
Lower River (downstream)	36,000	4

* Presented at 24th Annual Meeting, Ohio Sewage and Industrial Wastes Conference; Cincinnati, Ohio; June 28–30, 1950.

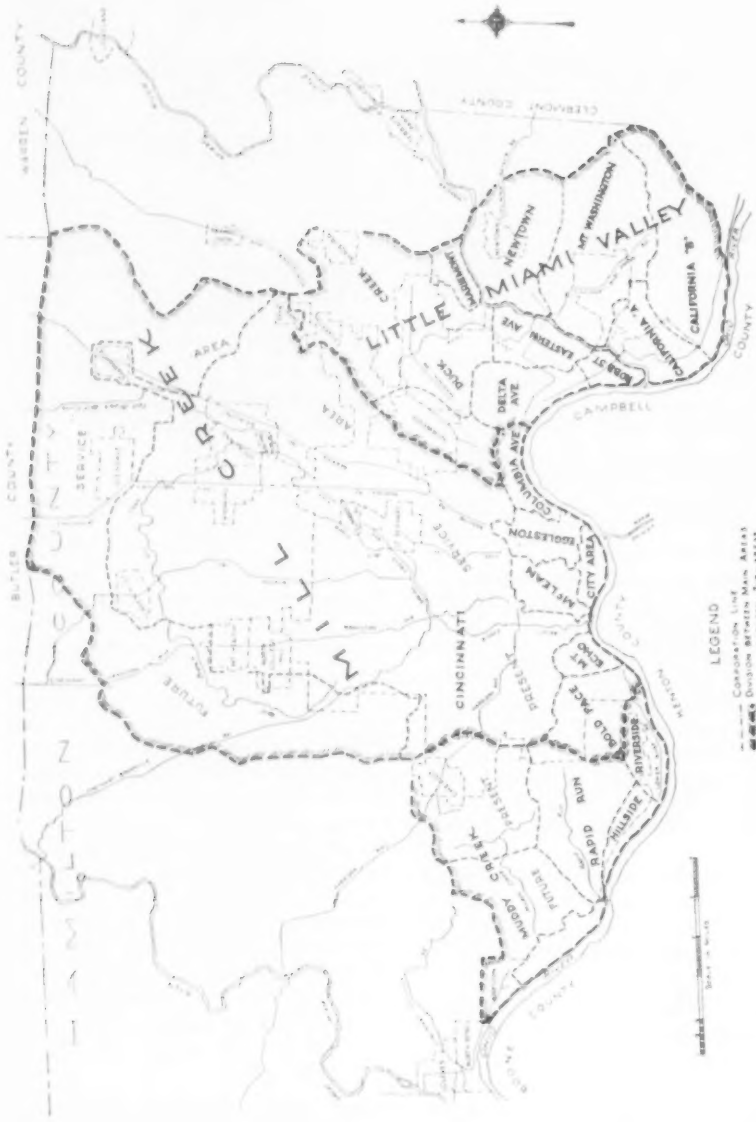

FIGURE 1.—Metropolitan sewer service areas of Cincinnati, Ohio.

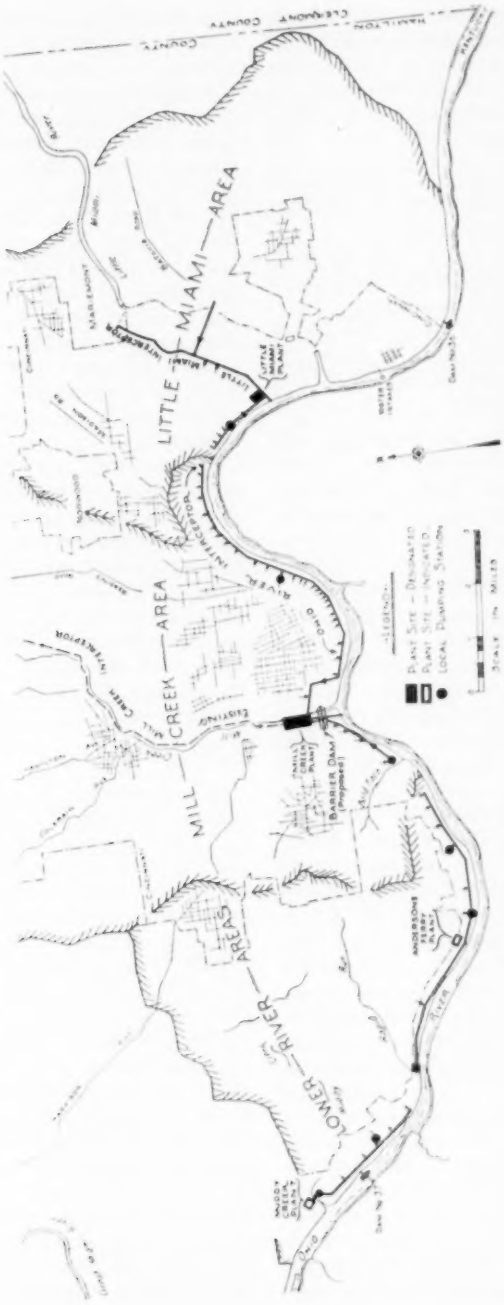

FIGURE 2.—Schematic plan for Cincinnati sewage disposal.

The topographical division of the area, coupled with studies of available sites and of problems of interception, led to the designation of four sites for location of treatment works (see Figure 2). These are:

1. A Mill Creek plant, located in the valley bottom just north of the Barrier Dam, for main works.
2. Smaller works for Duck Creek or Little Miami area, located on Kellogg Avenue near Lunken Airport.
3. For the Lower River, two plants are contemplated, one to serve the Muddy Creek district, and the other the Rapid Run district.

At each of the first two points the city has acquired land sufficient for the construction, and later possible enlargement, of necessary treatment facilities.

Interception of Sewage

Inasmuch as the sewers of the metropolitan area discharge into the Ohio River or into its Mill Creek and Duck Creek tributaries, treatment of the wastes at central points has involved problems of collection. In the Mill Creek and in the Duck Creek-Little Miami valleys, interceptors were planned and built during the period proximate to 1914 and were later extended, chiefly as a matter of local improvement. As a result, there is a Mill Creek interceptor with outlet capacity of 132 m.g.d. and a Duck Creek interceptor with a capacity of 86 m.g.d. The first of these is adequate for all normal sewage flows, but storm-water overflow regulators will have to be provided to extend the life of this large existing interceptor. Ultimately, it may require enlargement in order properly to protect the channel of Mill Creek from objectionable overflow. That depends to some degree on the plan for channelizing Mill Creek, which is another project the city has in mind. Incidentally, the city now has plans for replacing and enlarging the lower portion of the Mill Creek interceptor to serve as the outlet for the Mill Creek plant.

Interception from the combined sewer outlets into the Ohio River, and delivery of the sewage to the Mill Creek works, is quite a problem. It will require some 8 mi. of interceptor and at least three pumping stations. The difficulty is that of locating collector sewers low enough to intercept the wastes, yet high enough to avoid undue effects from changes of river stage. The margin between these limits is not great, and is further narrowed by the possibility that the Cincinnati pool may be raised to serve navigation.

Another factor helping to complicate matters is the much discussed development of the river front.

The interception for Ohio River collectors is planned for an average capacity-flow ratio of 3 to 1—that is, capacity for three times the average flow—but also with intent to vary this ratio with the concentration of the wastes contributed by an individual trunk sewer.

Degree of Treatment

It is interesting to follow progressing thought concerning treatment of Cincinnati sewage, not so much as bearing upon the degree of treatment as in portraying the equipment and devices that have become available for obtaining treatment results.

Early consideration of the subject is recorded in the classic 1913 report made by H. S. Morse as engineer-in-charge, and the late Harrison P. Eddy, consultant to the city. In that report, treatment of the sewage was envisaged as providing partial treatment and disinfection for Mill Creek wastes and secondary treatment, also with disinfection, at the Duck Creek or Little Miami site. Imhoff tanks, sludge drying beds, and trickling filters constituted features of the plants, according to this preliminary plan. Disin-

fection was in terms of chloride of lime. This, as stated, was in 1913.

During years following, pollution of the Ohio River received considerable attention from various agencies. Action in this direction started in 1924 and culminated as the Ohio River Sanitation Compact of 1940, which, in 1948, was made effective by all the signatory states. Essentially, this compact provides for minimum treatment of wastes signified by 45 per cent removal of suspended solids. Later, however, and as a result of public hearing, the Ohio River Valley Water Sanitation Commission used its authority to establish a heightened standard for the Cincinnati pool, expressed as 65 per cent reduction of B.O.D., but qualified to permit of lessened treatment under favoring conditions in the river.

With this standard fixed, it became a city obligation to devise works that would accomplish the desired results. Briefly stated, current plans for the treatment of sewage contemplate partial treatment, coupled with pre-flocculation with or without addition of chemical, and supplemented by disinfection. Important in this, however, is the reserve of area for extending the treatment to the degree of "complete," and again by requirement of the Sanitation Commission applied through the Ohio Department of Health.

General Plan Summary

Summarizing the general plan, the City of Cincinnati has set up an overall project of collecting and treating wastes from the metropolitan area at four sites. Land has been acquired for the two important works of the project, the intercepting sewer to serve the Little Miami works has been built, and the plant itself is the subject of equipment contracts already let and of a general contract, for which plans are about ready to be put out for bids. Particular works representing city thought in treating the sewage are considered in the following description of the Little Miami project.

Little Miami Project

For an understanding of the design of the Little Miami works, there should be appreciation of three conditions affecting design. First, there is the standard of the Ohio Valley Commission. Second, there is the fact that Little Miami sewage is relatively small in quantity and pollution effect, and fairly ample river dilution is usually available, although at times, quite low river flows are encountered. Finally, there are three water intakes (Cincinnati, Covington, and Newport) located near the Kentucky shore close to the mouth of the Little Miami River and, possibly, affected by that river under certain rare conditions of river and wind. The outfall for the Little Miami plant is about 2 mi. downstream from the mouth of the Little Miami River.

In order to meet the possible variable effects of these conditions, the Little Miami plant offers flexibility in that flocculation before settling is optional, as are addition of chemicals to aid in coagulation and also disinfection of the final effluent. Through selective operation of these several processes, it is expected that treatment effects can be adjusted to variations in river conditions.

More specifically, the works (Figure 3) provided consist of:

1. Pumping station equipped with bar racks.
2. Grit detritors.
3. Chemical building, which houses comminutors, chemical storage, chemical feed devices, chlorinators, and blowers.
4. An aerated channel to the settling tanks.
5. Combined flocculation-settling tanks, wherein flocculation is provided by paddle wheels, and sludge removal by rectilinear chain-driven scrapers.
6. Sludge digestion tanks with adjoining building, which contains sludge

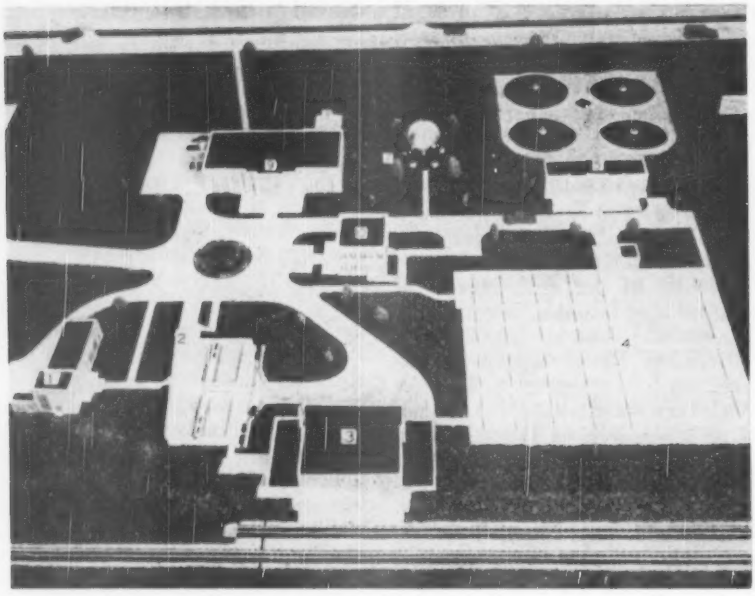

FIGURE 3.—Model of projected Little Miami sewage treatment plant, showing:

1. Pump building.
2. Grit chambers.
3. Chemical building.
4. Flocculation and settling tanks.
5. Sludge heating and gas building.
6. Sludge digestion tanks.
7. Gas holder.
8. Elutriation tanks.
9. Sludge disposal building.
10. Administration building.

preheaters and gas equipment, the latter connected to gas storage.

7. Sludge elutriation tanks.

8. Vacuum filters with sludge conditioning equipment.

9. Sludge incinerators.

10. Administration building.

The plant adjoins the former water works railroad, which will be used for the delivery of chemicals to the adjoining chemical building. The plant site is diked for defense against a 70-ft. river stage, and critical structures are anchored against floating. The operating elevations of the plant and tributary sewers are such that at a 20-ft. river stage, one contributing sewer will go out of action; at a stage of 37 to 42 ft. three additional sewers will be cut off. The plant will continue primary treatment up to a 46-ft. stage. At 70 ft. the dikes will be overtopped and the plant submerged. To meet this, provision has been made for unshipping pump motors for removal to the roof of the pump building, where the electrical transformers also are located.

Design Factors

The several structures of this plant incorporate factors of design as follows:

Plant capacity: 28.8 m.g.d. average (for the year 1980) and in which 40 per cent of the solids load will reach the plant during 8 hr.; maximum storm flow will be 86.3 m.g.d.

Detritors: Two units, one being used for average flow, with a detention

of 1.2 min. and a velocity of 0.55 ft. per sec.

Comminutors: Three units capable together of passing the maximum flow.

Chemical feed machines: In duplicate, each feeding alum at the rate of 1,000 lb. per hr., or 3 grains per gal. at twice the average flow.

Chlorination equipment: Three machines, each of 2,000- or 4,000-lb. capacity, depending on the orifice size. This signifies that, with one machine as standby, dosage would be up to 10 or 20 p.p.m. for 150 per cent of the average flow.

Blowers: Two of rotary type, each at 600 c.f.m., thus permitting one unit to supply air at 0.02 cu. ft. per gal. to 150 per cent of the average design flow.

Flocculator-settling tanks: Four units, each 185 ft. long, 41.5 ft. wide, and with water depth of 12 ft. in the settling end and 14.75 ft. in the flocculating portion. The two functions of flocculation and settling provide, for 1980 average flow, 55-min. flocculation and 90-min. settling. Flocculation is furnished by four variable-speed paddle wheels. Collection of the sludge is effected by straight line collectors in two parts to serve both flocculating and settling areas. Thus, with paddle wheels immobilized, the whole of the tank can be used for settling with a detention of 145 min. A sludge pump installation adjoins the settling tanks.

Sludge digestion tanks: Capacity of 357,000 cu. ft. in four 65-ft. diameter tanks with floating covers. For the ultimate 1980 flow, these tanks will provide 31-day storage for a 50 per cent removal of suspended solids, or 24-day storage when the removal is 70 per cent. Sludge will be preheated by gas-fired heat exchangers. A gas holder will have a capacity of 49,000 cu. ft. at 30-lb. pressure.

Sludge disposal: Designed for 24-hr. operation five days per week. It includes: elutriation, consisting of 3.4 hr. counterflow wash and settling; sludge dewatering on four filters which, for 1980 conditions, will enable dewatering at a 4-lb. rate with one filter as standby; sludge incineration in two furnaces of such capacity that, by working a 7-day week, one furnace could incinerate the 1980 solids representing 55 per cent removals.

Other features: Plant water for chlorination and elutriation will be obtained from two wells. End products (ash and grit)will be transported in trucks to fill. The plant effluent will be discharged to the Ohio River through a submerged outfall.

Program

As has been stated, contracts of the Little Miami project have been let for sludge filters and sludge incinerators in the aggregate amount of $209,097. Contract drawings for the balance of the plant have been completed. What expenditure they will involve is yet unknown, but it will be substantial.

Other projects in connection with the Little Miami sewage works are scheduled to follow in order and to be timed with construction of the plant; namely, Delta Avenue pumping station, Mt. Washington branch interceptor and pumping station, Robb Street connection, and the Little Miami interceptor connection at Duck Creek.

For the Mill Creek area, the first project contemplated is the Mill Creek outfall sewer, to be followed by projects for the plant. It is the intent of the city to prosecute design and construction work in a continuing sequence. From past performance, the

city can be relied upon to keep abreast of the development of sewage treatment in the Ohio Valley.

Because of necessary brevity, this presentation of the Cincinnati plan omits much. In particular, it fails to record the really impressive and detailed series of sewer gagings, sewage analyses, industrial surveys, field investigations, borings, and the like, which have characterized performance by the city. In part, these reflected various inherent difficulties, but, still more, it marks technical and administrative staff appreciation of the advantages of proper attack—appreciation that is rare, even though it does pay off.

II. METHOD OF FINANCING

By A. B. Backherms

Principal Engineer, Sewers and Sewage Disposal Section, Engineering Division, Cincinnati, Ohio

One must have plenty of patience, endurance, and fortitude to persistently promote a project, to carry on a campaign of education, and to sell the idea of the advantages of cooperation with neighboring communities. A project may have merit and be a necessity; nevertheless, how to finance the improvement is always the main deterrent.

Sewage treatment for Cincinnati had been discussed as early as 1912, but it required 26 years to hurdle the conversational barrier. Finally, in June, 1938, the Council authorized the city manager to make a survey and study for a sewage disposal system for the city of Cincinnati.

Another 10 years had elapsed before a ray of hope could be seen on financing. The latter occurred in May, 1948, when the Council passed an ordinance authorizing a sewer service charge to provide funds for the construction, management, operation, and maintenance of the sewage disposal system.

Program of Metropolitan Character

The topography of the area is such that the sewage from 21 neighboring incorporated municipalities and much of the county area is discharged into and through the network of city sewers. With two exceptions, this disposal service until recently has been enjoyed by the outside political subdivisions without cost to their constituents.

The problem of sewage treatment in this local area, therefore, is of metropolitan character; as a matter of equity, all of the beneficiaries should bear a proportionate share of the cost of the sewage disposal program. Generally speaking, there has never been any real vocal opposition to a program of sewage treatment. It was a question of: (1) Who is to sponsor the program? (2) Who pays? (3) How much? and (4) How soon?

The creation of a conservancy district was suggested as a logical procedure in initiating the program. However, the City Council frowned upon the idea of creating any new governing body and, instead, invited the beneficiaries to participate with the city. This closed the book on the sponsor of the program.

In Cincinnati, public recognition and support was evidenced by the passage of an initial $1,000,000 referendum bond issue in November, 1938, which encouraged the City Council to go ahead.

Methods of Financing

Many methods of financing the projects were considered; namely:

1. The use of general obligation bonds voted by the people, or author-

ized by Council, or a combination of both, to meet construction costs, and an appropriation from general funds for maintenance and operation. This was the most prevalent method in use when the study was made in 1938.

2. The use of general obligation bonds as above, and a special tax levy for maintenance and operation.

3. The use of general obligation bonds as above, and a sewer rental for maintenance and operation. This method was in vogue in many municipalities at the time and was becoming more popular.

4. Placing the sewage disposal system on a utility basis, issuing mortgage revenue bonds for capital cost, and making a sewer service charge for maintenance and operation.

5. The use of Council authorized revenue bonds for the capital cost, to be serviced as to debt service by the revenue from a sewer charge, which charge should be sufficient to provide for maintenance and operation.

There is no need of discussing the advantages and disadvantages of the various methods because they are common knowledge among most municipal officials. In general, however, general obligation bonds voted by the electorate must be guaranteed by a tax rate or general tax revenue to insure payment of the principal and interest when due. Therefore, they add to the general debt, on which there is a 5 per cent statutory limitation. Also, it would be quite difficult to secure a favorable vote simultaneously in all the cooperating municipalities.

General obligation bonds authorized by Council are in the same category as those voted by the electorate, but must come within the 1 per cent debt limitation. Also, the amount that can be issued in a single year is limited to 10 mills. Therefore, this type of bond cannot be relied upon to yield any substantial amount.

Mortgage revenue bonds must be guaranteed by a mortgage on the sewage disposal system established as a utility. Debt service obligations are met by a sewer rental. The bonds are not calculated in determining the net indebtedness and can be issued beyond the limiting per centum of net indebtedness.

General obligation limited revenue bonds, serviced by sewer service revenue collected from the users of the sewage disposal system, would be similar to those used by the Water Department. These bonds, as long as they are serviced by the sewer revenues, are not considered in computing the net indebtedness of the city.

Figures were available to indicate to each of the municipalities what its approximate proportionate share of the cost would be. In the early negotiations for an agreement, each agency wanted to exercise its prerogative of determining the best method of raising the money. This was agreeable to the city. All the complications that could result by independent methods of financing were anticipated, but since the Council had solicited the cooperation of the neighboring communities, it was only proper and courteous to permit the free expression of opinions.

From the beginning, the engineers recommended, that:

1. There be levied a sewer service charge to be applied uniformly throughout the entire metropolitan area of service.

2. Permanent improvements be financed from the sale of bonds, which would be amortized as to debt service from the revenue derived from the sewer service collections.

3. The expense of administration, billing, collecting, maintenance, and operation be paid directly from the sewer service charge revenue.

These recommendations were not without a vocal and active minority opposition, which developed in public hearings.

It should be appreciated that until the Ohio River Valley Water Sanita-

tion Compact was executed in June, 1948, there was no agency for instituting any valley-wide program of sewage treatment. Consequently, there being no need for hurry, the matter was allowed to drag.

In the meantime, to demonstrate sincerity on the part of the city of Cincinnati, legislation for the construction of the Little Miami Sewage Works was advanced to the stage of the final improvement report, which was referred to the Public Utilities Committee on June 5, 1940.

Construction drawings had been approved by the Ohio State Department of Health and the engineers were awaiting instructions to advertise for bids. But the council committee was reluctant to report back, being fearful to take the initial step in adopting such an innovation as a sewer rental in Cincinnati. Consequently, no funds and no construction.

It would be boring to go through a play-by-play narration of all that transpired in the ensuing years. However, some of the highlights on financing as expressed from time to time may be of interest. One suggestion was that the Water Department construct the sewage disposal system. Some of the twenty-odd satellite communities argued for a flat sewer revenue rate, others for a sliding scale. Some proponents had in mind an initial low-rate schedule with periodic step-ups as the construction program was developed. It was generally believed that periodic increases in rates would be a constant source of irritation, and that such a plan would jeopardize the favorable acceptance of subsequent and future sale of bonds, as well as have an adverse effect on the interest rate of the bonds. Another school of thought advocated the fixing of a rate schedule high enough to enable the city to accumulate a reserve, which rate and reserve would be sufficient to enable progressive installations of construction with peak requirements dated 8 to 10 years in the future.

The latter scheme, illustrated by Figures 4 and 5, was recommended and strongly supported by the engineering

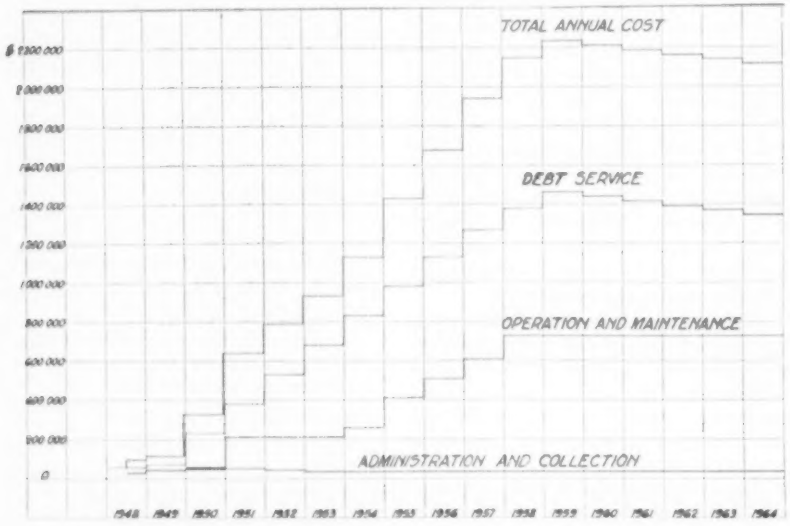

FIGURE 4.—Estimated annual cost requirements for Cincinnati sewage treatment program.

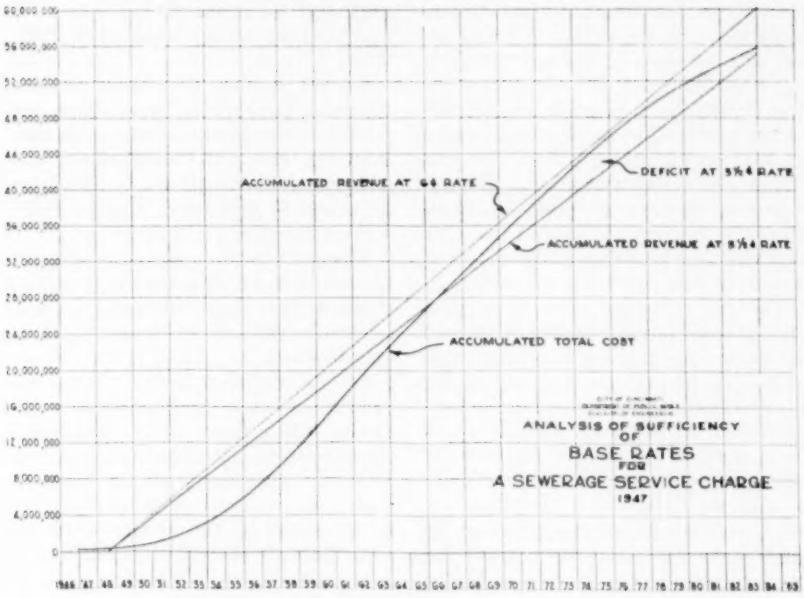

FIGURE 5.

division as being a more conservative and a sounder basis on which to launch the sewage disposal program. The wisdom of this plan was ultimately recognized and the plan was adopted.

Agreements

Negotiating agreements was a time-consuming operation. The engineers recommended a standard form of agreement, but each village solicitor had his idea of what should be in the contract. As a result two years would elapse and nothing would be accomplished. By this time, another group of officials generally had been elected in many of the suburban villages and they had to be informed on the subject.

The election in the fall of 1947 witnessed the failure of many of the incumbent officials in the villages to be re-elected which necessitated another start to acquaint the new officials with the problem.

Consequently, in January, 1948, the city manager again transmitted an agreement and advised each party that the city of Cincinnati must proceed with the development of the program and asked for a final commitment. This represented the fourth biennial attempt to revive metropolitan interest and cooperation on this sewage disposal project. Nevertheless, aside from the city of Norwood, which had signed an agreement in October, 1947, only five villages of 22 acknowledged receipt of the documents.

Finally an ordinance was adopted by the City Council on May 12, 1948, establishing July 1, 1948, as the effective date for collecting the sewer rental charges. The time allotted from the date of passage of the ordinance to the effective date, a matter of only six weeks, was at best too limited to properly prepare for collecting on 112,000 accounts.

Basically, the ordinance provides that a charge be made against all premises having an active sewer connection, based on the quantity of water used

therein, as determined by meter and irrespective of the source of water input, at a schedule of sliding rates starting with $0.06 per 100 cu. ft. for the first 60,000 cu. ft. monthly (or 180,000 cu. ft. quarterly) consumption, with a gradual reduction in rates for the higher consumption brackets. Exemption may be granted where it can be shown to the satisfaction of the city manager that a portion of the water as measured does not enter the sewer.

The city manager was authorized, also, to negotiate a contract with each benefited political subdivision connected to the city sewer system for the treatment and disposal of its sewage, based on the same conditions and charges set forth in the ordinance. If the agreement was consummated prior to and not later than December 31, 1948, retroactive charges were to be made and collected at rates prescribed in the ordinance. However, if the agreement was consummated after the deadline date of December 31, 1948, then the retroactive charges were to be made and collected at double the rates prescribed in the ordinance.

The significance of the double charge for retroactive billing was sufficient to obtain action; by the deadline date 21 villages and the county had executed a contract, leaving only one village, the council of which advised the city manager that it had decided to construct its own plant.

The ordinance required all private wells to be registered. However, as very few were registered voluntarily, the city had another time-consuming witch hunt. Nevertheless, persistence brought results and the survey disclosed 213 active wells within the metropolitan area of sewer service. All wells are now metered and well water used and returned to the sewer has produced a revenue in excess of $100,000.

On the negative side, there has been disclosed 1,369 septic tanks within and 8,700 outside the city limits. All, however, are within the metropolitan area of service, serving property for which no sewer is available. Consequently, these properties are exempt.

Throughout the years of discussion, as can well be appreciated, the City Council was urged from all sides to keep the rates low despite a rising trend in cost.

In view of fluctuating prices, one cannot state for certainty what the ultimate cost may be when spread over a period of years. Therefore, the construction program must be timed to match the amount of bonds that can be amortized by the revenue from the sewer service charge. This means an average construction program of about $2,000,000 to $2,500,000 a year.

Conclusion

The success of this innovation can best be judged by delinquencies in payment. Surprisingly enough, the delinquencies have not been any greater than before the sewer service charge was added on the water bill, and it has not been necessary to turn off water to enforce collection of any account.

It can be concluded, therefore, that the people are aware of need for sewage treatment, that they are in sympathy with the program, and that it only required some mandatory law and initiative of the local officials to launch the program.

Summarizing the situation: it was a long drawn out process calling for patience, endurance, and fortitude, but it was finally done.

III. INDUSTRIAL WASTES CONTROL

By H. H. Kranz*

Formerly City Engineer, Cincinnati, Ohio

The Federal Water Pollution Control Act, known as Public Law No. 845 and passed by the Eightieth Congress in 1948, as well as the Ohio River Valley Water Sanitation Compact, concluded the same year, make it mandatory for the city of Cincinnati and industry to reduce the polluting wastes being discharged to the Ohio River. How the city proposes to carry out the mandate, the scope of its sewage disposal program, what has been accomplished and is in progress, and its proposed method of financing the projects have been adequately covered in the preceding papers.

Need for Industrial Wastes Disposal Policy

The next step, and a very important one, is to work out an arrangement whereby the city can cooperate with local industries in the matter of disposal of industrial wastes.

Most authorities agree that it is unreasonable to exclude all industrial wastes from the sewers. It is generally a wise policy to admit to the sewer system organic wastes, after such preliminary treatment as may be needed to prevent undue burden on sewage treatment, and to exclude wastes having an injurious effect on the physical structures or interfering with the municipal sewage treatment processes.

As an approach to the problem, a comprehensive survey of flow measurements, as well as sewage analyses of all the sewer outfalls in the metropolitan area, was made by the city to obtain pertinent data. The field and laboratory investigations show that most of the sewers of the metropolitan area carry sewage and wastes, which is normal for an industrial city having combined sewers. There are, however, four sewers—Eggleston Avenue, Evans Street, McLean Avenue, and the Mill Creek interceptor—which carry unusual loads of solids. In the last two sewers named, the volume and characteristics of the wastes are particularly outstanding.

Sources of Strong Sewage

Quoting from the summary report prepared by the consulting engineers:

"Measurements and analyses of sewage and wastes, coupled with industrial surveys in the McLean Avenue, and Mill Creek interceptor districts, show that a substantial portion of the sludge-forming solids are contributed by six types of industry; namely, paper mills, distilleries, chemical plants, soap works, slaughtering and packing plants, and tanneries.

It is estimated that these industries contribute approximately 82 tons per day of sludge-forming solids, which is 49 per cent of the total suspended solids discharged from the whole area tributary to a Mill Creek plant. If these wastes were eliminated, the suspended solids of the sewage of the area would be reduced from the unusual value of 494 p.p.m. to a more nearly normal content of 253 p.p.m."

It is obvious that many of these industries have been operating for years in violation of the existing plumbing section of the Building Code.

The discharge of industrial wastes into sewers or watercourses often represents simply an easy method of disposing of spent or waste products, but it may signify poor "housekeeping" methods at the plants, and the loss of values. The dollar value loss may be a stimulant, which accounts for the present trend in industry, wherein considerable study is being given toward reduction of the wastes in the plant, process changes, and recovery methods, rather than one of treating the plant wastes.

* Deceased June 9, 1950.

Effects of Industrial Wastes

Aside from the increase in the cost of the municipal plant due to enlarged capacity requirements, increased facilities, and provisions for the solids and sludge produced, certain wastes have a deleterious effect on the sewers and plant structures and an undesirable effect on the sewage, due to the mixing and interaction of different wastes and the inhibiting effects upon treatment processes. These adverse conditions, therefore, call for some corrective activities.

Remedial Measures

There are, in general, three methods of approach to the problem of industrial waste disposal:

1. The city accepts all wastes and assumes all responsibility for disposal, either at its own expense, or with special charges to industry for this service.

2. The city rejects all wastes and places full responsibility on industry for the disposal of its own wastes.

3. A combination of the above, wherein industrial wastes are controlled and modified at the source to an extent which renders them acceptable for discharge into city sewers.

The first method is not a proper solution, because it would relieve the offending industries, who are responsible for the pollution or excess load, from any share in the cost of abatement or treatment. Thus, it would offer no restraint from unnecessary additional pollution or contributions.

For the city to assume all responsibility and make special charges to industry for this service may lead the city into an impractical, if not an impossible, situation. In some cases, it may require pretreatment at the site of the industry. For proper control and regulation, the industry may have to operate its business as dictated by the city. Certainly, industry would not care to surrender the control of its business.

The second method is an easy way out for the city; at least, it would appear so without further thought. However, this probably would be suicide for the engineer, who had designed the sewage works with the understanding that all industrial wastes would be excluded. The realization of such a utopian condition in a highly industrialized community is something out of this world. The city could not maintain a qualified staff of men to enforce such a rigid policy.

Therefore, the third method offers what appears to be a fairer approach. By designating appropriate uses of the sewer, the management of an industry has an opportunity to study its problem on its merit. It can decide for itself whether it is financially advantageous to pretreat, or to simply control or modify the waste at its source so as to meet city regulations.

Consequently, the city should adopt a policy that will permit selection of individual plant waste treatment for greatest over-all economy, with a proviso that industry pay for disposal service in proportion to the quantity and character of waste discharged to the sewer.

Industrial Wastes Ordinance

Currently, the sewerage service charge is only made on a volume-of-flow basis. However, one section of the ordinance calls attention to the exclusion of such wastes as will damage the disposal system or cannot be treated satisfactorily at the municipal plant; and, further, to wastes that impose an unreasonable burden on the sewage disposal plant. In such cases, the city manager may compel the pretreatment of the sewage or may recommend the levying of a surcharge. Incidentally, these efforts to regulate wastes entering city sewers will apply as well to wastes from communities or plants outside the city.

Management of industry apparently is agreeable to cooperate with the city on this waste disposal matter and is willing to proceed with whatever reasonable modifications are necessary to meet city requirements. Industry can do much by "inside treatment" to reduce both volume and strength of wastes and should be given ample opportunity to institute and effect these improvements. This would benefit both city and industry. On the other hand, many firms realize that some form of pretreatment will be necessary and required, and consequently have pressed for a more specific interpretation of the general statements contained in the paragraphs of the service charge ordinance relating to industrial wastes.

Accordingly, the engineers drafted a tentative industrial wastes ordinance, which in form is patterned after the "Model Ordinance" suggested by the Federation of Sewage Works Associations, as published in "Manual of Practice No. 3." The intent of the ordinance is to:

1. Establish characteristics of sewage and industrial wastes that are prohibited from discharge into the public sewers.

2. Define a "normal" sewage for the city of Cincinnati.

3. Set up limitations, beyond which industrial wastes otherwise acceptable for admission will be subject to pretreatment at the point of origin, and/or to a surcharge for constituents above "normal."

4. Fix rates for such surcharges where wastes above "normal" are permitted admission to the public sewers of Cincinnati.

These all supplement the industrial wastes section of the existing ordinance.

The highlights of the tentative industrial waste ordinance are briefly summarized in the following:

1. "Normal" sewage, as defined, contains suspended solids, 300 p.p.m.; B.O.D., 240 p.p.m.; and grease, 50 p.p.m.

2. Apart from all solid, semi-solid, or viscous substances, and liquid-carried wastes, which by the ordinance are excluded from the public sewers by reason of their deleterious effects, destructive action, odor, clogging potentialities, and inhibition on treatment processes, industrial wastes will be admitted to the city sewers by agreement and on approval of the city manager, but subject to the following limitations and/or to surcharges, when (a) The daily average of suspended solids and/or B.O.D. does not exceed two and one-half times the average daily concentration of "normal" sewage, with a tolerance for a 15-min. duration of a concentration not greater than five times, and (b) Emulsified oils or grease do not exceed 200 p.p.m., with total contributions from individual plants subject to control.

3. For wastes having constituents higher than the aforementioned limitations of concentration, pretreatment will be required.

4. Where pretreatment is required to produce an admissible waste, the pretreatment may be planned to modify the wastes so as to reduce the concentration (a) to that of "normal" sewage, or (b) to the limitation of concentration noted in 2 (a).

It was stated previously that six types of industries contribute about half the total suspended solids. If all this industrial waste were delivered to the municipal sewage works, it would produce an influent approximating 500 p.p.m. of suspended solids and 400 p.p.m. of B.O.D. These constituents are twice the average of the raw sewage at the sewage works in 50 industrial cities across the country, indicating the abnormality of the sewage in Cincinnati.

Local industries are aware of the problem and the necessity for some action in disposing of their wastes. Their managements realize that, as a matter

of equity, the city cannot be expected to carry the full financial burden of treating the excessively heavy industrial wastes.

In some cases it is more economical to pretreat the industrial waste at its source. On the other hand, there may be instances where, if the waste is not objectionable on other counts, it may be treated at the municipal plant at less expense to the industry. Industry knows its problems better than does anyone else.

The objective of the city is to cooperate with industrial management and to be reasonable in dealing with the problem, so as to minimize the expense in reaching the endpoint. Obviously, it is not possible to satisfy everyone, but when the ordinance is completed it will be presented to Council and, no doubt, passed.

It is felt certain that industry, which has given full cooperation in the past, will continue by helping the city evolve an industrial wastes ordinance that will be as nearly satisfactory to all as is possible.

CLEAN WATER IS EVERYBODY'S BUSINESS

Under the title "Clean Water Is Everybody's Business," the U. S. Public Health Service has recently issued an attractive 28-page booklet setting forth in simple, understandable fashion the problems of stream pollution abatement and prevention, as well as suggested steps in reading the objective of reducing or eliminating waterway pollution. Excellent pictorial presentation of the various phases of both the problem and the solution made for easier understanding of the points being made.

Pollution damage to such important water uses as public health, recreation, fish and aquatic life, industrial water supply, and agriculture is stressed in eye-catching form. Suggested remedial activities include development of comprehensive programs of stream survey, establishment of water quality standards, and stimulation of treatment plant construction.

Copies of the booklet are available at 20¢ per copy by requesting "Public Health Service Publication No. 11" from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

POLLUTION OF IRRIGATION WATERS

By C. T. Wright

Regional Engineer, U. S. Public Health Service, Denver, Colo.

Modern irrigation in the United States dates from 1847, when the Mormons first diverted surface water to irrigate desert land in the Great Salt Lake Valley of Utah. Irrigation contributed to early western development, and today it is playing a major role in the agricultural and economic development of the western states. In the arid and semi-arid sections of the West, water is considered one of the most valuable natural resources, and the full utilization of the limited water resources for all purposes is considered essential to its greatest development. More than half of the land area of the continental United States, consisting of 1,160,000,000 acres, is located in 17 [a] of the states west of the Mississippi River where irrigation for agricultural purposes is practiced extensively.

About one-half of all truck vegetable crops, and over three-fifths of the fruit produced, is raised in the West by irrigation. Of all crop production in the 17 western states, about 30 per cent is from irrigated land. In the mountain states, about 60 per cent of the total crop production is from irrigated land; in Nevada and Arizona, virtually all crops are irrigated. In the 6 plains states, only about 6 per cent of the total crop production comes from irrigated land, Texas leading this area with irrigated production of 15 per cent of all its crops. In terms of 1947 farm value, this irrigated production amounts to $2,400,000,000 (1).

[a] Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming.

Distribution of Rainfall in the Western States

With the exception of the western portion of the northwestern states, precipitation is inadequate for the growing of most agricultural products in the western states. As a result, irrigation is essential to agricultural production and development.

One-eighth of the area of the 17 western states averages less than 10 in. of precipitation a year. An additional one-fourth of the area has only 10 to 15 in. Still another fourth has only 15 to 20 in. A further one-fifth is in the rainfall belt of 20 to 30 in., which means a deficiency of moisture for many crops and frequently for all crops during vital growing periods. Only 15 per cent of the area of the 17 western states has 30 or more inches of rainfall (1). Additional information covering the distribution of rainfall in the western states is presented in Table I.

The Reclamation Program 1948–1954

Estimates indicate that 21,120,000 acres of land are under irrigation in the western states, leaving only 16,840,000 acres for possible development (2). A program for the utilization of this land is under way. The U. S. Bureau of Reclamation is supervising the construction of many new projects and investigating entire river basins to determine the manner in which maximum development can be attained. The trend is toward large multiple-purpose projects, which, in addition to supplying water for irrigation, will provide hydroelectric energy for public use, municipal water supplies, recreation

TABLE I.—Average Annual Rainfall (In Inches) in the 17 Western States [1]

State	Period	Eastern Division	Middle Division	Western Division	State Average
North Dakota	1892–1947	19.39	16.59	15.37	17.12
South Dakota	1890–1947	22.00	17.09	18.04	19.10
Nebraska	1876–1947	27.57	22.27	17.95	22.60
Kansas	1887–1947	35.29	26.44	19.12	26.95
Oklahoma	1892–1947	40.83	33.24	25.75	32.93
Texas	1888–1947	40.02	22.91	13.60	26.83
Montana	1895–1947	13.15	15.06	20.60[2]	16.28
Wyoming	1892–1947	—	—	—	16.70
Colorado	1888–1947	—	—	—	16.54
New Mexico	1892–1947	—	—	—	14.49
Arizona	1895–1947	—	—	—	13.85
Nevada	1889–1947	—	—	—	8.99
California	1897–1947	—	—	—	23.98
Oregon	1890–1947	14.12	—	53.73	26.31
Washington	1890–1947	16.76	—	57.47	34.59
Idaho	1894–1947	26.07[3]	15.71[4]	12.76[5]	18.18
Utah	1892–1947	14.39[6]	10.99[7]	—	13.41

[1] Source of information: U. S. Weather Bureau.
[2] West of the continental divide.
[3] Northern division.
[4] Southwestern division.
[5] Southeastern division.
[6] Great Basin drainage.
[7] Colorado River drainage.

facilities, fish and wild life conservation, and many other benefits.

"The Bureau of Reclamation's 1948–54 program for the conservation and development of western water resources would irrigate 2,036,000 acres of arid land within 7 years, creating about 24,000 new farms. It also proposes to provide a sorely needed additional supply of water to 3,607,000 acres of land consisting of nearly 66,000 farms now irrigated but short of water. This development requires a sizable investment, totaling $3,891,900,000 for the seven years. The regional studies indicate that water is available for the ultimate irrigation of 14,800,000 more acres of new land in addition to the 2,040,000 acres proposed under the 1948–54 program. This ultimate new land figure does not include range land susceptible of irrigation for pasture on which insufficient information is available" (2).

"Irrigation projects that were developed in the past generally provided irrigation water at a fairly reasonable cost. However, the majority of recent developments and projects currently under construction involve elaborate facilities for the storage and transportation of water which will increase the cost of irrigation. Under these conditions the cost of water to the irrigators may be increased; however, greater returns from irrigation should permit irrigators to pay for these developments. The anticipated increase in cost of water from current and future developments will probably involve the production of more truck and fruit crops that provide a higher monetary return. Since these products are usually consumed in the uncooked state, they provide the greatest health hazard when polluted water is used for irrigation purposes."

Figure 1 portrays the land use and irrigation possibilities (2) in the 17 western states located west of the Mississippi River. This chart illustrates the extent to which irrigation has been developed, and the potentialities of extending irrigation in the western states.

Water Supply

Irrigation farmers rely on two chief sources of water—surface and ground water. In many areas of the West, the combination of surface and underground water sources is important in providing irrigation water. The fact that more than three-fourths of all irrigated land in the West depends exclusively on stream flow, makes these waters of particular interest from a water pollution standpoint.

The need of water for agricultural, municipal, and industrial development has exceeded the natural supplies in many western communities. Both industry and agriculture have failed to take adequate measures to insure sufficient supplies of water to meet their expanded needs. In some cases, communities and industries have diminished potential water supplies by pollution of surface waters.

A large share of the water that becomes available for irrigation purposes originates in the mountains of the

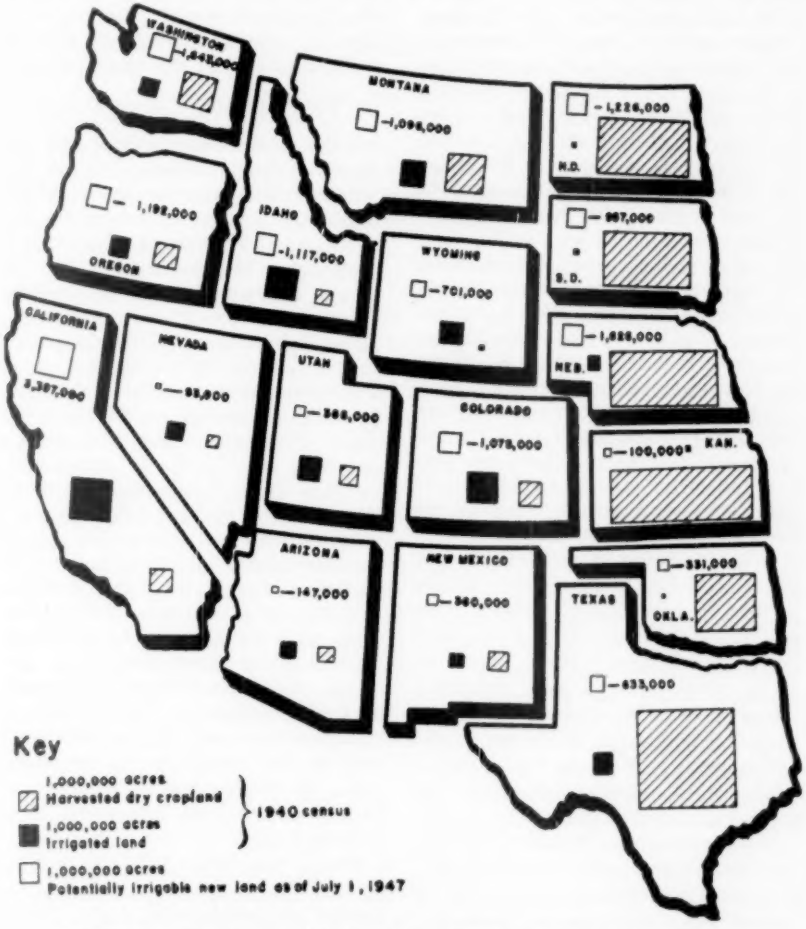

FIGURE 1.—Land use and irrigation possibilities of 17 western states (2).

West, where surplus rainfall and melting snow are collected and stored for use during the growing season. Water from this source usually originates in heavily forested and sparsely settled areas, where pollution of the source of supply is limited. Although the water is generally of good quality from a bacteriological standpoint when withdrawn from its source or storage, it becomes subject to pollution by domestic and industrial wastes as it flows through populated centers while en route to the areas where the water is used for irrigation and other purposes. Water stored in reservoirs located on the lower reaches of streams below population centers is subject to pollution by the discharge of wastes into streams that supply these reservoirs. Practically all of the water from the majority of western streams is allocated for various purposes, and during the irrigation season the major portion of the stream flow is diverted, thus reducing the amount of water available for the dilution of domestic and industrial wastes. The channels of these streams and their tributaries range in character from small washes, which are practically dry part of the time, to rivers, which flow continuously. In streams of intermittent natural flow, raw sewage, industrial wastes, and treatment plant effluents constitute most of the flow in certain areas during part of the year, and may be only a small part of the total flow at some places during periods of high runoff. Under these conditions, irrigation channels diverting from the streams below populated areas carry sewage and industrial wastes in varying degrees of initial treatment and stream dilution.

The increased demand for irrigation water has placed greater emphasis on the use of reclaimed sewage for irrigation purposes. This practice has been approved by the health authorities under certain conditions, and as it is feasible from an economic standpoint in some areas, a greater demand for reclaimed sewage is anticipated in the future. The trend in this direction has been demonstrated by a recent census of sewage effluent reclamation in the United States, which reveals that sewage disposal effluents are being used for the irrigation of crops in 124 localities (3). Although it is generally agreed that the use of raw or untreated sewage is unsatisfactory for the irrigation of crops from a public health standpoint, partially disinfected effluents from treatment plants are considered satisfactory for this purpose when the effluents are not used for the irrigation of fruits and vegetables that are to be consumed in the uncooked state.

Public Health Considerations

Prior to 1937, raw sewage was used for the irrigation of crops in some localities. This practice has been discontinued, however, due to the action of State and local health authorities in prohibiting or discouraging it. Although this problem has been solved, a large number of communities and industries continue to discharge untreated and partially treated domestic and industrial wastes into streams used for irrigation purposes. Available evidence indicates that health hazards are associated with the use of polluted water from these streams for the irrigation of fruits and vegetables that are consumed in the uncooked state, although the extent of these hazards has not been determined. These problems will become more acute with the increase in population and industrial development unless effective water pollution abatement programs are initiated in the western states. Some of the states have made considerable progress in this direction, but in others, plans for the control of pollution of irrigation waters are still in the development stage.

Public Law 845, which was enacted by the 80th Congress to control pollution of interstate waters, may assist in solving this problem.

Previous investigations have indicated that pathogenic bacteria found in practically all domestic wastes will persist for days in sewage-irrigated soil (4), as well as upon the outer skins and leaves of vegetation grown therein. Under these conditions it appears possible that the field workers, food handlers, and ultimate consumer are subject to infection in connection with the handling and consumption of fruits and vegetables that are irrigated with polluted waters. Although evidence tracing epidemics to such sources is inconclusive in many instances which have been subject to epidemiological investigation, Tanner (4) concluded in 1935 that, "Good epidemiological evidence seems to exist in the literature to the effect that fresh vegetables may, and have caused communicable diseases and that the sanitary condition of the soil from which they are harvested is important."

It has been the practice of some irrigators to wash their vegetables in irrigation ditches by leaving them submerged overnight. Bacteriological examination of the washings from these vegetables revealed that in some cases the vegetables were contaminated by polluted water that flowed in the ditches.

The use of polluted water for the irrigation of fruits and vegetables is also objectionable to the health authorities, as well as the ultimate consumer, from the standpoint of aesthetics. Aesthetic considerations are important, inasmuch as they may affect the market for produce from areas where polluted water is used for irrigation.

Cattle that have access to fields irrigated with polluted water present the problem of communicating infection to the animals and thence to consumers. Two cases of cattle being infected with *Cysticercus bovis*, or tapeworm, under these conditions have been reported. Cattle that pastured on a sewage irrigated farm in Melbourne, Australia, were infected with *Cysticercus bovis*, and the cattle that were slaughtered were responsible for the development of *Taenia saginata* in humans who consumed the beef (5). Discovery of infestation with *Cysticercus bovis* in beef cattle pastured in an Arizona field irrigated with partially settled sewage suggested the possibility that the worms had been transmitted through the sewage. It appeared that the cattle, in addition to grazing on the irrigated land, persisted in drinking the sewage effluent in preference to fresh water (6). There is also a possibility that the udders of dairy cows may be exposed to contamination in irrigation ditches and while grazing on fields that have been irrigated with polluted water. Infection from this source may be transferred to the ultimate consumer through unpasteurized milk.

Most bactericides, fungicides, insecticides, and herbicides, as well as certain plant hormones, salts of heavy metals, and many organic chemicals, render effluents unfit for irrigation use. Great care should be exercised in permitting the disposal of trade wastes into sewer systems if the effluent is to be used for irrigation waters. Effluents containing trade wastes should be looked upon with suspicion, as many substances found in such wastes may be toxic to plants and cattle (7).

Sanitary Requirements for Irrigation Waters

The question of sanitary requirements for irrigation waters is still an unsettled problem, and existing requirements indicate that there is a difference of opinion among health authorities regarding practical limiting values. No such exhaustive studies have been made on the sanitary quality of irrigation waters, comparable to those that established standards for drinking water, swimming pools, and shellfish waters. Investigations concerning the sanitary quality of irrigation waters and their relationship to the edible crops produced are a basic

need, especially in those areas with limited water resources where streams are used for waste disposal and the receiving waters are diverted for irrigation purposes. Inasmuch as no generally acceptable sanitary requirements are at present available for irrigation waters, decisions are based upon state laws and the scope of present knowledge, judgment, and past experience with the use of such waters.

Differences of opinion among health authorities, regarding the health hazards associated with the use of polluted water for the irrigation of edible crops, are reflected in the regulations of the western states where extensive irrigation is practiced. The requirements vary from the states where no formal regulations have been adopted, to requirements where treatment plant effluents used for the irrigation of vegetables and fruits for human consumption are practically equivalent to the bacteriological requirements of the drinking water standards. The regulations in California and Oregon require that effluents to be used for the irrigation of food crops must be well oxidized and conform to rigid bacteriological requirements. Colorado's regulations also require a high bacteriological standard for waters to be used to irrigate fruits and vegetables for human consumption. In a number of the western states permits are required before sewage effluents can be used for irrigation purposes.

During the Conference of State Sanitary Engineers in 1947, the subject of water supply standards for other than drinking water was discussed in considerable detail. It was the opinion of the group that there is a definite need for reasonable minimum requirements to cover the sanitary quality of irrigation waters. On this occasion the following resolutions covering water quality requirements for other than drinking water were prepared by the Water Policy Committee of the Conference of State Sanitary Engineers for adoption by the Association of State and Territorial Health Officers:

1. That the Public Health Service, in cooperation with State health departments and other agencies, organizations, and groups capable of rendering technical assistance, be requested to initiate such research and study as is necessary to determine reasonable minimum requirements for water used for irrigation of food crops, bathing, recreation, food and drinks processing, and water used in any way which may adversely affect the public health, and
2. That the Public Health Service, in cooperation with State health departments and other interested agencies and parties concerned, be requested to develop and assist in the adoption of recommended minimum requirements by State health departments and other interested agencies and parties.

According to Streeter (8), the problem of irrigation waters is one of growing public health significance because of the various types of salad and other raw consumption vegetables being grown in irrigated fields in large areas and shipped through interstate channels to all sections of the country. At the present time, no widely accepted standards exist for the quality of irrigation waters or the streams from which they are drawn. Standards of streams used for other agricultural purposes, notably for stock watering, need to be developed in more precise and comprehensive form. At present, opinions appear to diverge widely as to the degree of pollution which is safe for natural waters consumed by livestock. Limiting values for certain chemical pollutants toxic to domestic animals also need to be defined.

Existing and Proposed Studies

Basic research studies covering problems relating to the pollution of irrigation waters are being conducted at the present time. Three of these studies were made possible by funds allotted to private institutions by the Research Grants Division of the National Institutes of Health. The studies re-

ferred to, together with the institutions conducting the studies, and the dates they were initiated, are as follows:

1. The sanitary significance of sewage effluents applied to truck crops; Michigan State College. Initiated in 1948.

2. The incidence and significance of intestinal pathogens in sewage contaminated irrigation water and on food products irrigated with polluted water; University of Colorado Medical School. Initiated in July, 1948.

3. The study of the hazards of polluted irrigation water, its effect on soils, and related health problems; Texas College of Mines. Initiated in January, 1949.

Bacteriological studies on irrigated fruits and vegetables were initiated in July, 1949, in Denver, Colo., by the Environmental Health Center of the Public Health Service, Cincinnati, Ohio, to supplement the studies listed above. The preliminary work was initiated to determine the pollution being transferred by irrigation waters to the soil and vegetables in terms of coliform and enterococcus densities.

The health authorities interested in developing minimum requirements for waters to be used for the irrigation of food crops are of the opinion that existing research studies should be supplemented by an epidemiological investigation to determine the relationship between the use of fruits and vegetables that have been irrigated with polluted water and enteric infections. The Environmental Health Center of the Public Health Service plans to initiate an epidemiological study when funds become available for this purpose.

A conference on polluted irrigation waters, sponsored jointly by the Environmental Health Study Section, Division of Research Grants and Fellowships, National Institutes of Health, Public Health Service; the Texas State Health Department; and the El Paso City-County Health Department, was held in El Paso, Texas, on January 27, 1950, to discuss various phases of this problem and the results of current research studies. The results of the meeting were summarized as follows:

1. From the limited available epidemiological information it appears that no major public health hazards have developed from present irrigation practices; due largely to the vigilance and good practical supervision provided by health departments.

2. More research and studies are needed to develop methods which will permit further utilization of existing and potential irrigation waters. It is agreed that there is need for better indices of suitability of water for irrigation purposes and that further investigation of this subject is essential.

3. The United States Public Health Service should continue and expand its activity in stimulating and carrying out research in the entire field of irrigation water uses as related to public health.

4. Industry should be further encouraged in the development and use of vegetable washing and sanitizing equipment.

5. It is recommended that the economics of using sewage effluents as irrigation waters be included in the studies of the overall problem.

Requirements for Sewage Treatment

The report on "Salvage of Sewage" (9) concludes the discussion of public health considerations by the following excerpt:

> Thus it would appear that except for use upon vegetables to be eaten raw, an effluent from about the treatment afforded by subsidence, trickling filters, and secondary subsidence effecting about 85 per cent reduction in bio-chemical oxygen demand (B.O.D.) and suspended solids, followed by chlorination, should satisfy health requirements, and that the use of reclaimed water for irrigation of growing crops—as well as of processed sewage solids as fertilizer—may not be ruled out on strictly public health grounds.

This report (9) also summarizes the public health problems associated with salvage of sewage as follows:

Standards for the use of sewage and its by-products promulgated by health authorities afford the best criteria in this field, and in general imply that:

(*a*) Raw sewage, or its untreated solids content, or the soil which it has recently irrigated, shall not come in contact with foodstuff designated for human consumption, nor shall livestock graze upon pasture irrigated therewith;

(*b*) Forage crops which are to be harvested and cured may be irrigated with the untreated effluent from adequate subsidence tanks;

(*c*) For use in the cultivation of human foodstuff, particularly that to be eaten raw, the water reclaimed from sewage must be well oxidized and thoroughly sterilized at all times; and

(*d*) Sewage solids to be used as fertilizer must be digested and dried, or if undigested, may be kiln-dried at temperatures which will destroy all inimical pathogenic organisms.

The use of sewage effluents for crop irrigation purposes in California is covered by the following rules adopted in May, 1933, by the California State Department of Public Health (10):

Rule 3. Effluents of septic tanks, Imhoff tanks, or of other settling tanks, or partially disinfected effluents of sprinkling filters or activated sludge plants or similar sewages, shall not be used to water any growing vegetables, garden truck, berries, or low-growing fruits such that the fruit is in contact with the ground, or to water vineyards or orchard crops during seasons in which the windfalls or fruit lie on the ground. Such sewage, effluents, or any sludge or screenings shall not be permitted in ditches or pipes which may be used to irrigate vegetables, garden truck, berries, or low-growing fruit.

Nursery stock, cotton, and such field crops as hay, grain, rice, alfalfa, sugar beets, fodder corn, cowbeets, and fodder carrots, may be watered with such settled or undisinfected or partially disinfected sewage effluents provided that no milch cows are pastured on the land while it is moist with sewage or have access to ditches carrying such sewage. However, such sewage may be used for irrigating growing vegetables grown exclusively for seed purposes in fields where crops are raised and watered not in conflict with this rule.

Rule 4. The foregoing restrictions do not apply against the use of well oxidized non-putrescible and reliably disinfected or filtered effluents which always meet the following bacterial standard: In any 20 consecutive samples, from which five 10 c.c. portions each are examined, not over ten portions shall be positive for members of the Coli-aerogenes group, and in no single sample shall over half the 0.1 c.c. portions of the sample of the effluent be positive for the above organisms.

The works and methods used for the production of such oxidized and disinfected effluent must be correctly adapted to the purpose and designed with adequate factors of safety to produce uniformly a well oxidized, odorless, and inoffensive effluent, thoroughly filtered, treated, or disinfected to meet the above standards.

Where the reclamation of sewage is permitted for use in the cultivation of fruits and vegetables to be eaten raw, the majority of health authorities are in agreement that treatment plant effluents should be well oxidized and adequately disinfected.

As previously stated, no widely accepted requirements exist for the quality of irrigation waters or the streams from which they are drawn. Under these conditions, health authorities are faced with the necessity of recommending the type and degree of sewage treatment that should be provided when the effluent will be discharged into a stream to be used for the cultivation of truck crops, in the absence of basic supporting data. This condition applies where the quality of water for the irrigation of fruits and vegetables is of paramount importance. Until accepted requirements or standards become available, health authorities will have to base their decisions regarding the type of sewage treatment required to safeguard irrigation waters on past experience and available information on this subject, which is not entirely satisfactory.

South African Experience

The results of previous investigations in South Africa show that the use of polluted water for the irrigation of vegetables and pastures has been responsible for the transmission of waterborne diseases and infection from animal parasites in both humans and cattle (11).

Reports indicate that a large proportion of the native population in South Africa is infested with animal parasites (that is, worms) and the numbers of eggs, ova, and cysts that reach the sewer systems from this source is very great and constitutes a real problem. In view of the danger of transmitting these infections from the sewage disposal plant effluents, city officials in Johannesburg studied the problem to evaluate the risks involved in order to determine the type of sewage treatment that would be needed to assist in solving the problem. The five Johannesburg sewage disposal plants were studied for over a year, and the following results were summarized by Dr. B. M. Clark in a report to the Chief Medical Officer of the Union Health Department (12):

1. That the cysts of *Entamoeba histolytica* (amoebic dysentery), eggs of *Ascaris lumbricoides* (round worm), of *Taenia saginata* (tapeworm), and of *Ancylostoma* (hookworm), are frequently present in Johannesburg sewage as it arrives at the works.

2. That cysts or eggs have been found in screened sewage, settled sewage, primary filter, and humus tank effluent, and also in the effluent from activated sludge plants.

3. That in the samples examined, no eggs, ova, or cysts were found to have passed secondary sand filters (ordinary and Hamlin reversible types) or underdrained land filtration areas.

The results of these researches appear to indicate that as far as South Africa is concerned, the value of the secondary sand filter is brought into prominence. It is likely that in South Africa the slow sand filter will be, in the future, a compulsory adjunct to any sewage works from which the effluent is to be discharged into a stream or is to be used for irrigation on land on which crops for human consumption may be grown.

The fact that cysts and eggs of animal parasites are frequently present in South African sewage emphasizes the need for complete sewage treatment, including sand filtration, where the effluent is used for the irrigation of truck crops prior to or after dilution. This problem is not so acute in this country, and the use of sand filters as an adjunct to present methods of treatment is questionable. However, future studies should provide the answer to this problem.

Conclusions

The information presented emphasizes the importance of irrigation for the economic and agricultural development of the western states. In this connection, the pollution of irrigation waters is one of the problems that remains to be solved in some areas in order to permit the maximum utilization of available water resources. Differences of opinion apparently exist among health authorities regarding the health hazards associated with the use of polluted water for the irrigation of edible crops. This is reflected in the lack of uniform requirements or standards to cover this problem. As no widely accepted requirements or standards exist for the quality of irrigation waters or the streams from which they are drawn, there is a definite need for basic data on which reasonable requirements can be based.

No conclusions can be drawn at this time from current research studies covering problems relating to the pollution of irrigation waters, and it is the opinion of health authorities that more research and studies are needed to develop methods which will permit further utilization of existing and potential irrigation waters. These studies should be supplemented by an epi-

demiological investigation to determine the relationship between the use of truck crops exposed to polluted irrigation waters and enteric infections. There appears to be some agreement regarding the use of well oxidized and adequately disinfected effluents for use in the irrigation of fruits and vegetables. In the absence of widely accepted requirements or standards, health authorities are faced with the necessity of requiring a high degree of treatment for domestic and industrial wastes where irrigation waters are involved in order to eliminate possible health hazards.

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SLUDGE ELUTRIATION AT THE RICHMOND-SUNSET PLANT, SAN FRANCISCO, CALIF.*

By Keeno Fraschina

Superintendent, Richmond-Sunset Sewage Treatment Plant, San Francisco, Calif.

Previous to discussing experience with elutriation at San Francisco's Richmond-Sunset plant, a brief review is in order as to what elutriation is and why it is used. These remarks are confined to the elutriation of digested sludge, but the same general principles apply to the elutriation of other sludges as well.

Elutriation comprises, essentially, the removal of soluble decomposition products normally present in sludge by washing with water comparatively free of such compounds. There are four steps in the process:

1. The sludge is diluted with water.
2. The sludge and water are mixed thoroughly and rapidly to form a weaker solution of the dissolved decomposition products.
3. The washed sludge is removed from the mixture by sedimentation.
4. The weaker solution is decanted.

In two-stage elutriation the sludge is washed twice, using fresh wash water each time. In countercurrent two-stage elutriation, the sludge is also washed twice; but, instead of using fresh water each time, the solution decanted from second-stage washing is used for first-stage washing. This cuts wash-water requirements in half without appreciable loss in washing efficiency. The amount of soluble decomposition products removed is usually measured analytically in terms of alkalinity reduction, but is sometimes measured in terms of ammonium ion reduction.

The purpose of elutriation is to reduce the amount of coagulating chemical necessary to condition the sludge for vacuum filtration and to produce a sludge having more uniform coagulating and dewatering properties. Digested sludge normally contains decomposition products in sufficient concentration to form objectionable amounts of gelatinous precipitates with coagulating chemicals like ferric salts and lime, or aluminum salts and lime. These gelatinous precipitates not only consume excessive amounts of chemicals but also make the sludge difficult to dewater. Elutriation greatly reduces the concentration of soluble decomposition products. As a result, the sludge solids can be coagulated readily with small amounts of ferric salts or aluminum salts, without the use of lime, and are then easily dewatered on a vacuum filter.

The elutriation process was incorporated in the original design of the Richmond-Sunset plant on recommendation of the Board of Consulting Sanitary Engineers, composed of Harrison P. Eddy, Charles Gilman Hyde, Clyde C. Kennedy and Leon B. Reynolds, in order to:

1. Reduce ferric chloride requirements.
2. Eliminate the use of lime.
3. Produce a sludge with uniform coagulating and dewatering characteristics.

The process has been in continuous use since the treatment plant was placed in operation in 1939 and has successfully met design expectations. Facilities for two-stage elutriation are

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also being provided in the North Point sludge plant, now under construction.

Richmond-Sunset Plant Facilities

The elutriation system at the Richmond-Sunset plant was designed for continuous flow, countercurrent, two-stage elutriation at a rate of 100 g.p.m. sludge to 300 g.p.m. wash water. The original installation consisted of:

1. Two rectangular sedimentation tanks with mechanical scrapers, each with 2-hr. retention time and an overflow rate of 800 g.p.h. per sq. ft. The 47,000-gal. first-stage tank is 14.83 ft. wide, 50.5 ft. long, and has a water depth of 8.25 ft. The 55,000-gal. second-stage tank is of the same width and length, but has a water depth of 9.5 ft.
2. Two cylindrical mixing tanks, each 4 ft. in diameter by 7.5 ft. high, with motor driven paddles, and providing approximately 1-min. retention.
3. One displacement-type sludge pump for transferring settled sludge from the first washing stage to the second.
4. Meters for measuring sludge and wash water.
5. Forced-draft ventilation with discharge at the building roof.

When the treatment plant was enlarged, in 1948, a new primary digester was constructed and the existing primary digester was converted to a secondary digester. An additional displacement-type transfer pump was added to the elutriation system and piping changes were made to permit any combination of the following operations:

1. Two-stage elutriation of sludge from either digester.
2. Single-stage intermediate elutriation of sludge between primary and secondary digestion.
3. Elutriation of supernatant liquor from either digester.
4. Return of washed sludge from either washing stage to either digester.

Wash water is plant effluent (primary), which is diverted from the effluent channel after post-chlorination has been applied, and flows to the elutriation system by gravity. Chlorinated effluent is used to avoid the possibility of reintroducing pathogenic organisms into the washed sludge. Cost analysis shows this to be the most economical wash-water supply available, despite the fact that primary effluent has an appreciable coagulant demand, which adds to the chemical cost of coagulating the washed sludge.

Normal Operation

All sludge withdrawn from the digestion system is elutriated. Sludge to be dewatered on the vacuum filters is given two washings. Sludge from the primary digester to be elutriated before transfer to the secondary digester is given a single washing.

In two-stage washing, sludge enters the elutriation system at the first-stage mixing tank, where it is mixed with overflow water from second-stage washing. Sludge is removed from the mixture in the first-stage sedimentation tank and transferred to the second-stage mixing tank, where it is mixed with fresh wash water entering the elutriation system at this point. The sludge, in turn, is removed from the mixture in the second-stage sedimentation tank, where it is stored until withdrawn for vacuum filtration. Sludge does not accumulate in the first-stage tank, but is transferred continuously to second-stage washing. In single-stage elutriation, the washed sludge is transferred directly from first-stage sedimentation to the secondary digester.

The elutriation system is designed for gravity flow of wash water from second-stage to first-stage washing. The overflow weir in the second-stage sedimentation tank is 1 ft. 3 in. higher than that in the first-stage sedimentation tank. Spent wash water overflows from the first-stage sedimentation tank

to a raw sewage sump and is pumped back to the plant inlet.

Filtrate from the vacuum filters also flows through the elutriation system, rather than being returned directly to the plant influent. This is done on the theory that the ferrous salts, present in relatively high concentrations, may be partially oxidized to ferric salts, which in turn may help to produce a better settling sludge. There is no direct evidence, however, that either of these steps actually takes place.

The operation of the elutriation system is controlled by measurement of sludge accumulation and by regulation of sludge and wash-water flows. Sludge accumulations are measured directly by hand sampling, or indirectly by visual observation of tank overflows. The vacuum filters are ordinarily operated one shift per day five days per week. Sludge normally is allowed to accumulate in the elutriation system during night shifts and over week-ends. Excessive accumulations are removed by operating the vacuum filters for longer periods of time, or by returning excess sludge to the digestion system. Sludge and wash-water flows are regulated to maintain a sludge to wash-water ratio as close to 1:3 as practicable in both washing stages. The flow rates are approximately 100 g.p.m. sludge to 300 g.p.m. wash water.

Operating Experiences

Short-Circuiting

Soon after the elutriation system was placed in operation, it was discovered that considerable sludge was being carried out in the overflow and being recirculated through the plant. This condition persisted regardless of rate of flow and despite attempts at correction by adding coagulants or by keeping sludge accumulations to a minimum. It was then decided to make dye tests to determine whether short-circuiting was occurring. An inexpensive red dye (Pompacyl Carmine 2G) was used. The tanks were cleaned and filled with wash water. Dye was added at the tank inlets and travel was observed visually at the surface and by sampling below the surface. The main flow was found to be horizontally along the bottom with a sharp, nearly vertical rise at the effluent weirs. The first color appeared at the effluent weir within 10 to 15 min. after addition of dye.

On the basis of these tests, baffles were installed at the inlet end of each tank to obtain more uniform distribution of flow and to eliminate scour along the bottom. Vertical baffles were placed at the inlets from the mixing tanks and just inside the openings from the distribution channel; horizontal baffles were placed just below the bottom row of openings. On completion of the installation, dye tests indicated short-circuiting was virtually eliminated. When sludge washing was resumed, the effluent remained clear. Since that time, overflow suspended solids have been at a consistently low level, except at infrequent intervals when the system was overloaded with sludge.

Scum Formation

Occasionally it was found that considerable gas-buoyed scum accumulated on the surface of the first-stage sedimentation tank. This condition was corrected by the installation of water sprays discharging parallel to the surface toward the inlet end of the tank. The water spray releases the gas so that the sludge particles, being no longer buoyant, readily settle out.

Elutriation of Supernatant Liquor

A two-stage digestion system was contemplated in the original design. However, owing to lack of funds, only a single digester was constructed. The design capacity was 0.8 cu. ft. per capita and supernatant liquor was returned directly to the plant inflow. Despite the rather limited digestion capacity available, digestion was very good. Reductions in volatile matter in

the neighborhood of 65 per cent were obtained consistently. However, in the digester there was very little stratification into clear supernatant and "thick" bottom sludge. The total solids content of supernatant liquor returned to the plant inflow was often as high as 1.5 per cent, leading to a serious problem of sludge recirculation. In order to alleviate this condition, it was decided to try elutriating the supernatant liquor. After making necessary piping modifications of a minor nature, it was found that suspended solids could be removed from supernatant liquor by elutriation just as effectively as from bottom sludge. Elutriation of supernatant liquor was then instituted as a permanent operating feature and has practically eliminated solids recirculation from this source.

Elutriated Sludge

The elutriated sludge has averaged between 4.5 and 5 per cent total solids. This concentration appears to be obtained regardless of the solids content of the sludge being elutriated. The alkalinity reduction is approximately 80 per cent. The approximate alkalinities (as $CaCO_3$) of the digested sludge, elutriated sludge, and wash water are 2,000, 400, and 200 p.p.m., respectively. The amount of ferric chloride required to coagulate the sludge for vacuum filtration has varied from 4.5 per cent on dry solids in 1939 to 3.3 per cent at present. There is also a seasonal variation, which depends largely on the quality of the wash water. The amount of ferric chloride required drops to a little less than 2 per cent during the winter months, when there is much storm-water dilution of the wash water, and rises to a little over 4 per cent during the dry summer months.

Intermediate Elutriation

Intermediate elutriation of sludge transferred from the primary digester to the secondary digester was started on an experimental basis in July, 1949, on completion of the two-stage digestion system. The purpose was to determine the effects on sludge separation in secondary digestion. Single-stage washing, as previously described, was carried on without interference with normal elutriation of secondary bottom sludge. The sludge settled out readily in the secondary digester, leaving a clear supernatant liquor not exceeding 1,300 p.p.m. total solids. The settled sludge had an average total solids content between 5 and 6 per cent. In April, 1950, intermediate elutriation was discontinued and direct transfer of sludge from the primary digester to the secondary digester was started. It is too early to draw definite conclusions as to the relative merit of the two methods of operation. Nevertheless, it appears that intermediate elutriation produces a more concentrated sludge and a clearer supernatant, and adds flexibility of operation to the digestion system.

Conclusion

The elutriation system has proven itself in actual operation to be a very valuable and necessary part of the plant treatment processes. It has not only fulfilled design expectations of reducing coagulant requirements and producing sludge with uniform coagulating and dewatering properties, but also has been utilized effectively in removing suspended solids from digester supernatant liquor. It has increased the flexibility of operation of the two-stage digestion system and shows promise of increasing its capacity.

LITERATURE REVIEW ON THE OCCURRENCE AND SURVIVAL OF ENTERIC, PATHOGENIC, AND RELATED ORGANISMS IN SOIL, WATER, SEWAGE, AND SLUDGES, AND ON VEGETATION

II. Animal Parasites *

By Willem Rudolfs, Lloyd L. Falk, and Robert A. Ragotzkie

The following portion of the literature survey is concerned with those pathogenic and parasitic organisms of animal classification which are most likely to be transmitted through the handling or eating of raw fruits and vegetables. They may be considered as divided into protozoa and helminths. The most important of the former, from the standpoint of the problem under study, is *Endamoeba histolytica*, the cause of amebiasis and amebic dysentery. Among the helminths can be mentioned the tapeworms, *Hymenolepis nana;* the roundworms, *Ascaris lumbricoides* and *Trichuris trichiura;* and the hookworms, *Necator americanus* and *Ancylostoma duodenale*.

Endamoeba histolytica

Craig (20) lists five species of amoebae found in the intestinal tract of man. Only one, *Endamoeba histolytica*, is definitely known to be disease-producing. The most important modes of transmission of the organism are considered to be contaminated water supplies, foodstuffs grown on contaminated soil or handled by "carriers," and flies.

Winfield and Chin (54), in studying the epidemiology of this amoeba in northern China, found that evaluation of the part played by vegetables in its spread was difficult. In northern China, where nightsoil was worked into the soil, the amebic infection rate was higher than in southern China, where pouring wet feces directly over vegetation was more frequently practiced. They concluded that vegetable fertilization was not so critical a factor in the spread of dysentery as the part played by food handlers.

Aldridge (1) reports the following incident experienced by sanitary officers of the United Nations Relief and Rehabilitation Administration:

> Museirat, the Greek refugee camp near Gaza, Palestine, housing nearly 10,000 refugees, reported a high incidence of amebic dysentery. The source of infection was traced to the fresh vegetables bought by refugees from the natives. In this whole area, human excreta were used for fertilizing vegetable gardens. The refugees were advised to cook all vegetables before consumption. However, it soon became apparent that it was impossible to stop them from buying and eating uncooked vegetables. Upon the recommendation of the camp sanitary engineer, a central canteen was set up by the camp staff to buy all fresh vegetables and fruits from the natives and sell them to the refugees at cost. Within this canteen, all vegetables and fruits were immersed in a 200-p.p.m. hypochlorite solution for one-half hour and then rinsed in clear water to remove the chlorine taste. This operation brought about a substantial reduction in the number of reported dysentery cases.

Early experimental work on the longevity and resistance to germicides

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of *E. histolytica* cysts depended on the eosin staining test as the criterion of living cysts. This has been largely superseded by more accurate cultural techniques and, thus, must be borne in mind in evaluating results.

Boeck (9)(10), using the staining technique, ascertained that cysts of *E. histolytica* were viable in distilled water for at least 153 days at 12° to 22° C. Other intestinal amoebic cysts were alive after periods ranging from 32 to 244 days. The thermal death point was found at 68° C. for *E. histolytica* cysts. York and Adams (56), using cultural methods, found this death point at 50° C., but the cyst could stand 45° C. for 30 min.

Mills, Bartlett, and Kessel (35) concluded that cysts, like bacteria, would not penetrate the stem end of fresh vegetables to any great extent. The most effective method of killing protozoan cysts and helminth eggs, as well as pathogenic bacteria, on fruits and vegetables was dipping into boiling water for 10 sec. The eosin staining method was used for cyst work.

Dobell (23)(24), who studied free amoebae of *E. histolytica*, found that they could survive three days in water at room temperature and some as long as five weeks at 37° C. The cysts, on the other hand, were found to survive up to 37 days at room temperature, but died in a few days at 37° C.

Hegner (31) noted that chronic amoebic dysentery attacks in a small Guatemalan missionary settlement greatly diminished when a drilled well and oil-driven pump were installed as protection for the water supply.

In an effort to evaluate the pollution of hands of careless carriers, Spector and Buky (45), using the staining technique, found that few *E. histolytica* cysts survived five minutes drying on human hands polluted with the cysts.

In 1949, Beaver and Deschamps (7) reported that *E. histolytica* cysts survive from 6 to 8 days in moist soil. Cyst viability was checked by cultural techniques. The soil used was a dark loam, containing 30 to 50 per cent fine sand. The cysts were washed and then worked into the top 10 to 15 mm. of soil. This, plus the fact that the studies were made in the tropics during the rainy season, tended to nullify the effects of desiccation on the cysts. The temperature during the period of the test ranged from 28° to 34° C. It is the opinion of the authors that the death of the cysts was due to the high temperatures.

The survival of *E. histolytica* in drinking water and in present water treatment plant practice has received considerable attention within the last 30 years.

Wenyon (52) found that 100 p.p.m. of chlorine in water had no effect on *E. histolytica* cysts, even after several hours' exposure (eosin staining technique). York and Adams (56), using cultural methods, concluded that the same concentration would kill the cysts in 30 min.

Spector, Baylis, and Gullans (44) and Baylis, Gullans, and Spector (6) studied the efficiency of rapid sand filters and chlorine in removing and killing *E. histolytica* in water. The eosin staining technique was used for the chlorine studies. Their results indicated that coagulation and filtration with rapid sand filters were capable of removing over 99.99 per cent of the cysts added to the test water. The amounts of chlorine or chloramine required to kill the cysts were far in excess of those used in public water supplies, but chlorine was more effective than chloramines. As much as 500 p.p.m. of chlorine were not always able to kill all cysts in 48 hr. However, the kill was better in unbuffered solutions, indicating a possible pH effect caused by the chlorine.

Bolduc (11) found that cysts of the dysentery amoeba may live in water for months, but are killed in 5 min. at 65° C. and in 10 min. by drying at

room temperature. To kill the cysts with 500 p.p.m. of chlorine required 10 min.

Stone (49) used both staining and cultural methods to evaluate the resistance of *E. histolytica* cysts to chlorine. He concluded that the cysts were no more resistant than colon bacilli. The ortho-tolidine and neutral starch iodide tests used to evaluate chlorine concentrations were found to give false readings in the presence of large amounts of organic matter and to this he attributed the high chlorine dosages other investigators found necessary to kill the cysts.

Brady, Jones, and Newton (12) also found sand filters effective barriers against the cysts. Using calcium hypochlorite to treat raw water in Lyster bags, they found that the cysts are not completely killed with practical chlorine doses except after at least 20-min. exposure. Doses of 7.5 p.p.m. of chlorine were able to kill the majority of the cysts, giving considerable protection against amebiasis under field conditions.

Kessel *et al.* (33) found that 0.3 p.p.m. of residual ozone was more effective than 0.5 to 1.0 p.p.m. of residual chlorine in killing *E. histolytica* cysts. Also, the activity of chlorine decreased at higher pH values.

Chang and Fair (17), Chang (16), and Fair, Chang, Taylor and Wineman (25) studied the viability of *E. histolytica* cysts in water and their destruction by certain germicides. Cultural methods were used in all the work. The survival time of the cysts was about 90 days at 0° C. and was reduced by one-third for each 10° C. rise in temperature. The survival in sewage and natural waters showed about the same results.

The cysticidal efficiencies of chlorine and chlorine compounds depended upon the temperature, chlorine dose, contact time, cyst concentration, hydrogen-ion concentration, organic matter present, and the form in which the chlorine was added. In general, the chlorine dose required decreased by about 40 per cent for each 10° C. temperature rise and by some 20 per cent for each doubling of contact time. The cysticidal dosage did not decrease below 2 p.p.m. except at high temperatures and long contact periods. The dosage also increased by some 30 per cent for each doubling of cyst density. Lower pH values (6 to 7) were more favorable for the action of chlorine than high values (7 to 9). The concentration of chlorine required to destroy cysts lay well within the range of super-chlorination if contact time of 30 min. or longer were used. The death of colon bacilli preceded that of *E. histolytica* cysts.

Comparison of free chlorine, hypochlorite, and chloramine solutions indicated that at 18° C. and pH 7.0 the above order was that of decreasing efficiency in cysticidal activity. The presence of sewage complicated matters because of the presence of ammonia, which produced chloramines with free chlorine. Also, the presence of organic matter decreased the chlorine efficiency markedly and the chloramine efficiency but slightly. Soluble organic matter was more influential than suspended organic material.

Synthetic detergents were tested for their cysticidal properties. Four cationic detergents were found effective cysticides, a neutral detergent less so, and anionic detergents were of little value. Contact time of 10 min. at 30 p.p.m. or 2 hr. at 10 p.p.m. was recommended. However, the tendency of water so treated to foam, as well as the unknown human physiological effects of these detergents, kept their use in experimental stages. The possibility of their use in safeguarding cooking utensils and raw fruits and vegetables was suggested.

Becker, Burks, and Keleita (8) felt that cultured cysts used by Chang might be more resistant to chlorine than cysts freshly isolated from in-

fected patients. Results presented indicated the probability that chlorination of drinking water in practical amounts could not be depended upon to kill all *E. histolytica* cysts. Cultural methods were used to test viability.

Gordon (29) found viable cysts of all five intestinal amoebae, including *E. histolytica*, in a 3-yr. examination of Moscow sewage. Furthermore, sedimentation up to 6.5 hr. with and without coagulation with ferric chloride failed to remove all cysts. Chlorine concentration up to 12.7 p.p.m. residual had no effect on *E. histolytica* within 30 min. Consequently, viable cysts were found in the sewage plant effluent.

Hamlin (30) reported the following conclusions from the sampling of sewage in five Johannesburg, South Africa, sewage treatment plants. Cysts of *E. histolytica*, as well as eggs of parasitic helminths, were frequently present in screened and settled sewage and in trickling filter, humus tank, and activated sludge effluents. However, effluents of secondary sand filters or of underdrained land areas showed no cysts or eggs.

Summary and Conclusions

In summary, the following conclusions may be drawn from the literature concerning the cysts of *Endamoeba histolytica* and their behavior in water sewage, and soil, and on vegetation:

1. The disease caused by these organisms is essentially water-borne, although the role played by nightsoil and vegetation has never been clearly delineated. The role of "carriers" is also of no small importance.

2. The cysts may survive for weeks, possibly months, in water and sewage.

3. The methods used to test the viability of cysts have, until recently, been open to considerable criticism as to reliability. In early chlorine studies, the observed resistance of the cysts may have been due, in part, to false chlorine determinations.

4. The early chlorine studies indicated that a minimum of 100 p.p.m. of chlorine would be required to kill *E. histolytica* cysts. However, more recent results indicate such values are not necessary, but that they are on the order of 2 to 15 p.p.m. The form of the chlorine varies in its efficacy, free chlorine being more lethal. The cysticidal activity of these chlorine compounds depends on many factors, among which are temperature, concentration, contact time, and cyst density. Quaternary ammonium compounds (cationic detergents) were also found to have cysticidal properties.

5. In water and sewage treatment, sand filters were found to retain cysts most efficiently.

Helminth Parasites

Helminth parasites of particular interest here are certain intestinal roundworms and tapeworms. Although the organisms are very widespread, infecting millions of people, the importance of the role of raw fruits and vegetables in their dissemination is not clearly understood.

Faust (27) discussed the relationship between nightsoil disposal and the propagation of helminthic disease in China. Foodstuff may become contaminated with eggs or larvae either through careless handling or the use of nightsoil as fertilizer. Sterilization of nightsoil was most likely to reduce these diseases, but it had to wait upon development of a cheap potent agent with possible fertilizer property before it could fit into Chinese economy. The possibility was suggested of composting nightsoil for a period of time determined to be sufficient to allow the most resistant types of larvae or eggs to die off.

Stiles (48) listed the reaction of hookworm eggs and larvae to various temperature ranges. The lowest temperatures at which eggs will hatch

larvae that reach the infecting stages were 8° to 10° C. The most favorable range was from 20° to 35° C., but eggs will hatch at 40° C. Both eggs and larvae could withstand 40° to 50° C. for a few minutes and 50° to 60° for 1 to 5 min. Above 60° C., however, the eggs and larvae were killed almost instantly.

Investigations on the control of hookworm disease in the West Indies have been made by Payne (41), Augustine (2) (3) (4) (5), and Cort (18). Among their findings were the following:

1. The infectious larvae were generally limited to a life in the soil of 6 to 12 weeks under favorable conditions.
2. Larvae died out in 3 weeks at 35° C., in somewhat over 9 weeks at 27° C., in 10 to 12 weeks at 15° C., but in only 1 week at 0° C.
3. Direct sunlight caused almost complete drying out in 5 days, whereas shady soil was more favorable to the larvae.
4. Soils covered with vegetation were more favorable for larval development.
5. Water-soaked soils produced a rapid death rate.
6. Larvae could be carried about on soil adhering to shoes.
7. The larvae crept up vegetation and decayed wood as far as moisture films extended, but were rarely found on leaves of green plants.

Cort *et al.* (19) studied hookworm disease in China in relation to vegetable cultivation and viability in soil and nightsoil. Experimental turnip crops were fertilized with a mixture of one part of heavily infested feces and ten or more parts of water. Only a few eggs hatched into larvae, the high death rate being attributed to rapid surface drying. Hoeing gave greater larval development. These workers concluded that the use of human feces on vegetables constituted only a slight source of infestation, but this might become considerable when fertilization was done in wet weather on shaded plots, or where broken soil surfaces existed.

In stored nightsoil diluted with water, eggs were 90 per cent killed in about eight to twelve weeks in spring and in about four to six weeks in summer (average temperature over 70° F.). Dilution with urine instead of water hastened the death rate so that 99 per cent of the eggs were killed in two to three weeks in summer. With lime additions, larvae failed to develop after one to twelve days' treatment, depending on the lime concentration.

Hirst (32) found as many as 250 hookworm eggs per gram of silt in the main sewers of a Ceylon system. Larvae were infrequent. Septic tank sludge averaged 28 hookworm eggs per gram in addition to *Ascaris* eggs. As many as 330 eggs per liter of sewage had been encountered. In a small treatment plant with three Imhoff tanks in series, the final effluent contained 30 eggs per liter (15,500 per liter in the influent), over 98 per cent being removed in the first tank.

Nicholls and Gunawardana (37) found that composting nightsoil in Ceylon produced an odorless manure free of *Ascaris* eggs, with only larvae of free-living nematodes present.

Winfield and Chin (53), investigating fecal-borne diseases in China, felt that direct contamination of the environment—and not vegetables—was the critical factor in the spread of *Ascaris lumbricoides*.

Yoshida (58) found that mature eggs of *A. lumbricoides* were still viable after five to six months under layers of soil in winter. Immature eggs subjected, in addition, to seven to eight months in the laboratory were still viable. He also found (57) that exposure to strong sunlight checked egg development and eventually killed them.

Ascaris eggs are extremely resistant to many chemicals which are ordinarily lethal. Galli-Valerio (28) found that

Ascaris eggs could develop to the embryo stage in 50 per cent sulfuric, hydrochloric, nitric, or acetic acids; saturated solutions of copper sulfate, ferrous sulfate, and copper acetate; and in 50 per cent commercial formalin or 50 per cent antiformin. Martin (34) found that the eggs of the closely related pig *Ascaris* will resist freezing and remain viable in Nebraska soil over the winter.

Cram (21) also found that pig *Ascaris* eggs showed great resistance to low temperatures. The eggs developed embryos (at 24° C.) even after 40 days exposure to − 2° to − 16° F., the longest period of exposure tested. Developed embryos, however, were killed in the eggs by a 20-day exposure to − 6° to − 17° F. Ten days at − 6° to − 17° F. or 30 days at + 12° to + 18° F. did not kill them. This worker concluded that severe winter weather and cold cannot be relied upon to destroy the viability of these eggs in pens and pastures. The ability of these eggs to develop was also found to be destroyed by immersion for 10 hr. in 5 per cent carbolic acid, or 5 hr. in 3 per cent cresol.

Ransom and Foster (43) found that eggs with embryos could be kept alive for several hours in carbolic acid.

Caldwell and Caldwell (14)(15) point out that desiccation is the greatest lethal factor to the development of *Ascaris* eggs and any forces which hasten or retard drying (such as temperature, humidity, and plant or insect life) are important.

Brown (13) found that the type of soil was an important factor in the rate of development and viability of *Ascaris* and *Trichuris* eggs. Experiments in Panama showed that *Ascaris* eggs in feces deposited on sandy soil in the sun were degenerated in 21 days. In the shade, however, 91 per cent of the eggs contained motile embryos in 35 days, and decreased to 69 per cent in 54 days.

Ascaris eggs developed in feces deposited in clay, loam, or humus soils, even in the sun. In the shade, development was higher. In 21 days in the sun, development was 54 and 71 per cent in loam and clay, respectively, whereas in the shade the values were 89 and 85 per cent. Development in humus soils was at least 20 days behind the others.

Otto (39) studied the moisture requirements of the eggs of several ascarids. He found that human and pig ascarid eggs did not develop to embryonation in atmospheres of less than 80 per cent relative humidity, although they remained viable for varying lengths of time in atmospheres containing less moisture. They appeared to be similar in their resistance to desiccation in partially dry atmospheres. As the temperature increased, the moisture requirements of the eggs also increased.

Spindler (47) found the *Trichuris* incidence in Virginia to be lower than that of *Ascaris*, except where the soil moisture was high because of shading. Developing and dead *Trichuris* eggs were frequently found on unshaded doorways of infested families, but fully embryonated, infective eggs were rarely found. On the other hand, embryonated eggs were often found when the doorways were in damp shaded places. He also found from laboratory experiments that *Trichuris* eggs require more moisture for development, whereas they die under moisture conditions favorable for *Ascaris* development.

Spindler (46) also found the number of embryonated eggs to be surprisingly small in spite of the fact that the soils were, in many cases, being subjected to continuous pollutions. As these eggs are known to remain alive for years in water in the laboratory, it appears that *Ascaris* "die much more rapidly in the soil than is commonly believed."

Owen (40) observed that the dog ascarid, *Toxocara canis*, survived the

winter months in Minnesota soil. He found that a snow blanket kept the soil relatively warm (minimum 5° F.), even though the air dropped to as low as − 24° F. (− 31° C.).

In Kentucky and Minnesota, eggs disintegrated before reaching the infective stage in summer soils exposed to the sun. Soil temperatures as high as 132° F. (55° C.) were obtained. Shaded sandy soils gave greater disintegration than did shaded humus soils in Minnesota, but disintegration was not apparent in shaded clay and sand soils after 42 days in Kentucky during July and August.

Laboratory tests showed that at 27° to 30° C. a relative humidity of 75 per cent is the minimum to permit complete development.

Wright, Cram, and Nolan (55), who surveyed 26 sewage sludge samples of 16 California and Arizona municipalities and three national parks, found but one tapeworm egg of the genus *Hymenolepis*. In 75 army camp samples, 27 helminth eggs were found, mostly those of *Ascaris lumbricoides*, *Trichuris trichiura*, and *Hymenolepis* sp. Eggs were found in raw sewage, but chiefly in sludges. Eggs were viable in sludge, which in some cases had been drying 62 days on sand beds. It was indicated that sewage sludge, indiscriminately used as fertilizer, might serve to disseminate eggs of intestinal parasites.

Cram (22) studied the effects of sewage treatment processes on helminth eggs and protozoan cysts. It was found that primary settling did not completely remove *E. histolytica* cysts, whereas hookworm and *Ascaris* eggs were removed more effectively, but not completely. The eggs can also pass through trickling filters and activated sludge treatment. Chemical treatment of secondary effluents, or intermittent sand filtration, removed both cysts and eggs. This is in essential agreement with the results of Hamlin (30) in Johannesburg, South Africa.

In sludge digestion at 20° to 30° C., the viability of *Ascaris* eggs was little affected after three months, and 10 per cent were still viable after six months. Even at greenhouse temperatures, a high percentage was viable after three to four months. Hookworm eggs survived digestion for shorter periods: 64 days at 20° C.; 41 days at 30° C.; and 36 days at room temperature. *E. histolytica* cysts were viable for 12 days at 20° C., 10 days at 30° C., and 4 days outdoors (− 12° to 19° C.).

Ascarid eggs were viable in drying sludge for 118 days and for 170 days under greenhouse and outdoor drying conditions, respectively. They were still viable in sludge with less than 10 per cent moisture but not less than 4 per cent. It was concluded that ordinary sludge drying would not completely destroy ascarid eggs. Hookworm eggs hatched in drying sludge and larvae were alive for as long as 62 days, or until the moisture fell to 10 per cent. Thus, sludge drying may also fail to kill all hookworms.

Newton, Bennett, and Figgat (36) conducted laboratory tests on the effects of various sewage treatment processes on the eggs of the beef tapeworm, *Taenia saginata*. Using an 18-in. column of raw sewage, they found that 65 per cent of the eggs settled at a rate of 0.6 in. per min. or faster, 16 per cent at rates of 0.3 to 0.6 in. per min., and 17 per cent at rates of 0.15 to 0.3 in. per min. It appears that although sedimentation at moderate overflow rates for 1 to 2 hr. will remove the majority of the eggs, a significant percentage would escape in the effluent.

Trickling filters at slow rates showed about 30 and 38 per cent removal of the eggs in two tests. This indicated the inadequate protection given to receiving streams by this process.

Slow sand filters, on the other hand, at rates of 1 m.g.a.d. completely

checked the passage of the eggs (one exception, 0.4 per cent recovery, in 7 trials).

Aeration in the activated sludge process for 5 months showed no effect on the eggs except slow reduction in numbers which could have passed out the effluent. Anaerobic sludge digestion for 6 months at 75° to 85° F. showed 30 and 46 per cent of the eggs to be normal in appearance in two trials.

Vassilkova (50) studied the viability of helminth eggs in pit latrines. In open latrines, eggs died within 6 months; in buried pits, however, 10 to 13 months were required for 100 per cent kill (97 per cent in 6 to 8 months). For dehelminthization of feces, he recommended burying them in early spring for 8 months to take advantage of the more rapid death rate in summer. Feces diluted with water (1:1 by volume) took 20 months for 95 per cent destruction of eggs. Therefore, dilution was not recommended for manuring vegetables and berries to be eaten raw.

Vassilkova (51) also studied the contamination of sewage farm vegetables with helminth eggs. Nineteen eggs, chiefly of *Ascaris*, *Trichuris*, and *Taenia*, were found per liter of sewage. Soil irrigated with this sewage contained 57 eggs per 6,600 gm. of soil. Contamination of vegetables was as follows (numbers contaminated per 100 specimens): cucumbers, 5 to 7; tomatoes, 3 to 16; carrots, 2. Only 36 per cent of the *Ascaris* eggs were viable.

For the protection of the vegetables, the following recommendations were made:

1. The sewage should be stored for 2 hr. to settle out about 72 per cent of the eggs. The sludge could be used for manure after composting.

2. Irrigation through trenches should be practiced with cucumbers growing on wide beds, carrots on beds 15 cm. high, and tomatoes growing without irrigation after flowering.

3. All vegetables eaten raw should be gathered into baskets without being laid on the ground.

The following conclusions were drawn from the survey on the parasitic intestinal helminths.

1. The eggs of these organisms are fairly resistant in soil, sludges, and nightsoil, depending on external conditions.

2. The eggs of the genus *Ascaris* are the most resistant of the eggs of this type of organism not only to chemicals and disinfectants, but also to environmental conditions.

3. Survival in soils and sludges depends on the maintenance of a certain minimum moisture and on temperatures below the lethal death point. Low temperatures are survived, although development is retarded.

4. The type of soil and shading determine the moisture and temperature conditions so that they greatly affect the survival of eggs.

5. Vegetables grown in soil contaminated with infected sewage or nightsoil may be a source of infection, but a comparison with other sources of infection has never been clearly demonstrated.

6. Stored nightsoil or sewage sludge may contain viable eggs for several months, but composting for a sufficient period appears to result in a comparatively safe, useful product.

7. Very complete sewage treatment is necessary to completely free the liquid from helminth eggs.

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FEDERATION ACTS ON MATERIALS ALLOCATION

Steps leading to recognition of the urgency of water resources conservation through abatement of pollution by municipal and industrial wastes discharges were taken by the Board of Control at its meeting on October 12, 1950, in conjunction with the Annual Meeting of the Federation. Foremost among the actions in this respect was passage of a resolution for presentation to the Congress and national defense agencies urging that construction and operation of all facilities contributing to pollution control be expedited during the present emergency by:

"1. Allocating, or otherwise insuring by proper priority designation, the availability of sufficient materials and equipment so that municipalities and industries will not be hindered in building necessary sewage and industrial waste treatment systems or in operating or maintaining existing facilities.

"2. Appointment of a qualified representative in the sewage and industrial wastes field to advise the National Securities Resources Board, the National Production Authority, or other responsible agency in respect to such allocations."

The salient points of the resolution, drawn up by a special committee of the Board, are called to the attention of interested parties in the hope that individual and organizational support will be enlisted in furtherance of the aims outlined, through written and personal contact with Congressional representatives and allocation and defense authorities.

USE OF FINAL SETTLING TANKS WITH STANDARD-RATE TRICKLING FILTERS

By John R. Thoman

Sanitary Engineer, Environmental Health Center, U. S. Public Health Service, Cincinnati, Ohio

Introduction

Since 1939, the Public Health Service through the Environmental Health Center at Cincinnati, Ohio, has conducted an "Inventory of Water and Sewage Facilities in the United States." This tabulation of basic data is carried out in cooperation with the sanitary engineering divisions of the various state health departments; its success is due to the excellent cooperation of these organizations.

As part of the Inventory, statistical summaries of sewage works practice are prepared; recent ones include a general summary of sewage works practice (1), and a report on sewage chlorination practice (2).

Data Included

Standard-rate trickling filters are represented in more secondary treatment plants than any other single process; being used in more than 50 per cent of all secondary treatment works. The importance of this method of biological treatment is evident both from the standpoint of numbers currently in use and those presently being constructed.

This paper, based on the 1948 edition of the Inventory (unpublished) reports what presently exists as regards the use of final sedimentation tanks with standard-rate trickling filters. It does not show present practice as regards new plants, which is determined in specific instances by the various state regulatory authorities.

Tabulated information is presented in Tables I, II, and III, each of which shows the number of plants and the estimated population served for standard-rate trickling filters with and without final settling tanks. Table I presents these data by states; Table II, by population groups based on the 1940 census population of the community in which they are located; and Table III, by geographical areas as used by the Census Bureau. In a few cases, filters are followed by some other secondary process than a final settling tank; these are covered by footnotes to Table I. In other cases, the trickling filter is not the only secondary process represented in the plant; however, these situations are few in number and have not been noted, as in practically all instances the filter is followed by a settling tank.

Discussion

Data presented in the foregoing tables show that 34.3 per cent of the standard-rate trickling filter plants are not equipped with final settling tanks. These same plants serve about 20 per cent of the population connected to trickling filters.

Recently tabulated information (3) indicates that there were 6,058 sewage treatment plants in the United States in 1948, of which 2,917 were classified as secondary. These secondary treatment plants served a total of 22,700,000 persons. Trickling filters were used in 1,517 plants serving almost 9,100,000 people. From these data it can be noted that trickling filter plants without final tanks comprise about 18 per cent of the secondary treatment plants in the United States, and serve about 8 per cent of the population connected to secondary treatment.

Oklahoma and Texas have the larg-

TABLE I.—Number of Trickling Filter Plants with and without Final Settling Tanks and Estimated Population Served, by States

State	Standard-Rate Trickling Filter Plants Having			
	Final Settling Tanks		No Final Settling Tanks	
	Number of Plants	Est. Pop. Served	Number of Plants	Est. Pop. Served
Alabama	6	19,600	4	8,420
Arizona	1	16,000	2	6,800
Arkansas	4	38,000	6	12,230
California	21	189,800	27	62,460
Colorado	1	1,600	8	33,820
Connecticut	2	26,000	—	—
Delaware	5	12,905	—	—
Florida	2	4,750	—	—
Georgia	18	178,800	18	40,370
Idaho	2	15,000	1	1,000
Illinois	119	512,815	8	20,670
Indiana	38	183,396	6	10,000
Iowa	90	472,810	48[1]	81,140
Kansas	78	201,990	7[2]	5,680
Kentucky	26	114,915	7	7,480
Louisiana	7	28,800	17	53,500
Maryland	10	872,550	1	700
Massachusetts	11	391,400	—	—
Michigan	8	246,320	6[3]	8,585
Minnesota	75	183,905	1	900
Mississippi	1	12,000	6	22,900
Missouri	50	145,080	26	37,595
Nebraska	17	21,230	26[4]	111,490
New Hampshire	3	2,500	—	—
New Jersey	46	293,560	6	20,475
New Mexico	4	36,800	12[5]	75,150
New York	44	178,230	8	100,425
North Carolina	14	154,950	18	51,150
North Dakota	1	15,000	8	55,700
Ohio	56	882,600	12[6]	167,400[7]
Oklahoma	12	76,870	91[8]	254,900
Oregon	12	36,100	1	7,500
Pennsylvania	58	367,490	11[9]	86,000
Rhode Island	1	12,000	—	—
South Carolina	7	59,000	13	70,780
South Dakota	21	75,950	10	15,520
Tennessee	5	29,150	5	15,900
Texas	26	784,985	84[10]	341,110
Virginia	23	54,125	11	15,270
Washington	4	29,180	—	—
West Virginia	4	20,100	1	18,500
Wisconsin	64	251,200	3	4,950
Wyoming	—	—	1	1,000
Total	997	7,249,650	520	1,827,470

[1] 2 plants with sand filter following filter serve 780 persons.

[2] 2 plants with oxidation pond following filter serve 1,050 persons.

[3] 1 plant with sand filter following filter serve 2,620 persons.

[4] 1 plant with application to land following filter serves 800 persons.

[5] 2 plants with application to land following filter serve 3,150 persons.

[6] 4 plants with sand filter following filter serve 11,800 persons.

[7] One-half of population served by Cleveland Southerly plant assumed as being treated by trickling filter portion of plant.

TABLE II.—Number of Trickling Filter Plants with and without Final Settling Tanks and Estimated Population Served, by Community Population Groups

Community Population Group	Standard-Rate Trickling Filter Plants Having			
	Final Settling Tanks		No Final Settling Tanks	
	Number of Plants	Est. Pop. Served	Number of Plants	Est. Pop. Served
Less than 500	50	17,720	31	19,940
500 to 1,000	159	107,080	92	60,585
1,000 to 5,000	480	980,765	293	522,930
5,000 to 10,000	158	846,500	56	314,010
10,000 to 25,000	94	1,096,135	33	328,415
25,000 to 50,000	28	809,800	6	167,300
50,000 to 100,000	11	603,550	4	206,000
Greater than 100,000	17	2,717,100	5	208,200
Total	997	7,249,650	520	1,827,470

est number of trickling filter plants without final tanks—91 and 84, respectively. These same states also have the largest connected populations. In 16 states, the number of plants without final tanks exceeds or equals those having such tanks. However, in only 9 states does the connected population exceed that served by plants with final tanks.

On the basis of population groups, the percentages of trickling filter plants without final tanks are largest in communities of less than 5,000 population. Approximately 37 per cent of the trickling filter plants in these groups do not have them. In communities of 1,000 to 5,000 population, 20.7 per cent of the total number of secondary plants are trickling filters without final tanks.

In general, the practice of not using final tanks with trickling filters is most predominant in the southern groups of states. In the West South Central group, 41.9 per cent of the secondary

[8] 1 plant with oxidation pond following filter serves 1,000 persons.

[9] 2 plants with sand filter following filter serve 1,300 persons.

[10] 5 plants with oxidation pond following filter serve 10,190 persons; 1 plant with application to land following filter serves 27,000 persons.

TABLE III.—Number of Trickling Filter Plants with and without Final Settling Tanks and Estimated Population Served, by Geographical Areas

Geographical Area	Standard-Rate Trickling Filter Plants Having			
	Final Settling Tanks		No Final Settling Tanks	
	Number of Plants	Est. Pop. Served	Number of Plants	Est. Pop. Served
New England[1]	17	431,900	———	———
Middle Atlantic[2]	148	839,280	25	206,900
South Atlantic[3]	83	1,357,180	62	196,770
East North Central[4]	285	2,076,525	35	211,605
East South Central[5]	38	175,665	22	54,700
West North Central[6]	332	1,115,965	126	308,025
West South Central[7]	49	928,655	198	661,740
Mountain[8]	8	69,400	24	117,770
Pacific[9]	37	255,080	28	69,960
Total	997	7,249,650	520	1,827,470

[1] Me., N. H., Vt., Mass., R. I., and Conn.
[2] N. Y., N. J., and Pa.
[3] Del., Md., D. C., Va., W. Va., N. C., S. C., Ga., and Fla.
[4] Ohio, Ind., Ill., Mich., and Wis.
[5] Ky., Tenn., Ala., and Miss.
[6] Minn., Iowa, Mo., N. D., S. D., Nebr., and Kans.
[7] Ark., La., Okla., and Tex.
[8] Mont., Idaho, Wyo., Col., N. M., Ariz., Utah, and Nev.
[9] Wash., Ore., and Calif.

plants are of this type; in the East South Central group 25.8 per cent; and in the South Atlantic group, 23.3 per cent. Considering population, 22.6 per cent of that served by secondary treatment in the West South Central group is served by this type of plant. The presence of over one-third of such plants in two states tends to unduly influence this area comparison, however.

Information concerning the construction dates of those trickling filter plants without final tanks is as follows:

Period	Number of Plants
Prior to 1920	58
1920–1929	175
1930–1939	167
1940–1948	54
Unknown	66

Of those plants for which dates are available, about 88 per cent were constructed prior to 1940. It is valid to assume that the 66 plants of unknown construction date, were also built prior to 1940, as the Inventory has been conducted since that time and most of the later dates are complete. Using this assumption, almost 90 per cent of the trickling filter plants without final tanks were built prior to 1940.

On the basis of these data it appears that the existence of trickling filter plants not incorporating final sedimentation is significant. This knowledge, however, is tempered by the apparent trend toward the use of final tanks. Present criteria of state regulatory bodies have not been explored in this regard.

The practice of not using final tanks is most predominant in the southern groups of states, and in communities of less than 5,000 population. Of perhaps more significance is the division in former practice along state lines. Although in many states it is more or less equally divided, in those having the largest numbers of trickling filter installations, practice usually is divided quite sharply.

Summary

Statistical data from the 1948 "Inventory of Water and Sewage Facilities in the United States" are presented showing the use of final settling tanks in connection with standard-rate trickling filters. Tables arranged by states, community population groups, and geographical areas show the number of plants and the population connected in each category. Over 34 per cent of such plants do not have final tanks. However, they serve only 20 per cent of the population connected to trickling filters. Trickling filter plants without final tanks comprise 18 per cent of the secondary treatment plants in the United States. The practice of not using final tanks predominates in the West South Central group of states, where almost 42 per cent of the secondary treatment plants are of this type.

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20-YEAR JOURNAL INDEX

Publication by the Federation of the 20-Year Index to *Sewage Works Journal* puts at the fingertips of all interested persons the key to the great fund of technical knowledge contained in the first twenty volumes of the Journal, wherein is stored the record of the period of greatest progress in the field. For those engaged in research, design, operation, maintenance, and administration of sewage works, industrial wastes treatment, and pollution abatement activities it is a necessary informational "tool."

Copies of the Index are available from The Garrard Press, Champaign, Ill., at $4.50 per copy.

Industrial Wastes

CRITICAL REVIEW OF LITERATURE ON THE TOXICITY OF INDUSTRIAL WASTES AND THEIR COMPONENTS TO FISH

I. Alkalies, Acids, and Inorganic Gases

By Peter Doudoroff and Max Katz

Biologists, U. S. Public Health Service, Cincinnati, Ohio, and Members, Committee on Research, Subcommittee on Toxicity, Section I, Federation of Sewage Works Associations

General Introduction

The literature dealing with the toxicity of industrial wastes and their various components to fish is extensive, but much of it is more misleading than instructive. Several comprehensive reviews and summaries of the literature have been published. Suter and Moore (104) and Belding (7) compiled much of the available early information, and a very satisfactory review was published by Redeke (77). The detailed treatise on the toxicology of fishes by Steinmann (99), based chiefly on the findings of European investigators, also is still of considerable interest for students of this subject. Helfer (43) adequately summarized German literature only. The comprehensive summary compiled by Ellis (28) probably is the one which is now most frequently referred to in the United States. Although some errors and other defects have been noted, this summary has proved very helpful.[1] The more recent, concise summaries by Cole (14) and Southgate (95) also deserve mention. The need for a more critical review, involving careful appraisal of methods and conclusions through detailed comparative study of most of the original published data, has been apparent. Several years will be required for completion of such a comprehensive review, which has been undertaken.[2]

Although a number of comprehensive studies published before the year 1910 (67)(110)(62) are of historical interest and may still have value, this review has been planned as a guide to more recent literature only. The earlier material is not, as a general rule, considered or cited. Publications more than 25 years old are summarized and discussed fully only if deemed exceptionally important. Reference is made occasionally to unpublished data and manuscripts, mimeographed reports prepared for limited distribution, and similar sources of information. No attempt has been made, however, to collect and to consider fully most of the extensive and interesting material of this nature that may be available. Inasmuch as its continued,

[1] It is noteworthy that the lowest concentrations of some toxic substances (for example $ZnSO_4$, CO, CO_2, and $CdSO_4$) reported by Ellis as having been lethal to fish are far above the minimum lethal levels. Solutions 10 to more than 1,000 times more dilute can be fatal to many species of fish under certain conditions. Ellis warned against arbitrary application of the lethality data, but this advice is not always heeded.

[2] The valuable assistance of John B. Owen, who did much of the preliminary bibliographic work, is gratefully acknowledged.

ready availability to all interested workers is uncertain, its value as reference material is limited. Furthermore, a thorough search for such information would be an exceedingly difficult undertaking.

Critical concentrations of toxic waste components (that is, minimum concentrations lethal or harmful to fish) have been arbitrarily stated, by many authors, without clearly specifying the conditions under which these values are applicable and valid.[3] In view of the wide disagreement between the findings of different investigators, it is evident that such generalization is fundamentally unsound and misleading. The minimal harmful concentration of a toxic substance may vary greatly, depending on the duration of the test, the species and age of the test animals, the dissolved mineral content of the water used as a solvent or diluent, the concentration of other waste components having a pronounced synergetic or antagonistic effect, the temperature, and other factors. No justification can be found for ignoring or minimizing the influence of these important variables. It is intended herein to formulate only cautious conclusions, or generalizations, which appear to be in agreement with most of the pertinent published data. Safe concentration limits of toxic waste components are not definitely prescribed.

Whether a certain concentration of an industrial waste, diluted with the water of the receiving stream, is or is not demonstrably toxic to local fishes can best be determined directly by biological test. The practical toxicity bioassay of a complex waste usually is less difficult than a complete chemical analysis. Also, it can yield information about the toxicity of a mixture in question which is far more reliable and pertinent than that to be found in the literature. The published data should be regarded chiefly as an aid to the understanding and application of bioassay results and of observations made in the field.

Peculiarities of the behavior and appearance of fishes affected by toxic substances, as well as other symptoms of intoxication, have been fully described by many investigators. These observations have led to much speculation concerning the nature of the lethal action of the different poisons. No attempt is made to summarize and discuss most of this information. It is of interest chiefly to specialists engaged in physiological or toxicological research, and its practical value is still quite uncertain. Some characteristic symptoms undoubtedly are indicative of certain types of poisoning. However, expert judgment, based on extensive experience, usually is required for reliable interpretation and evaluation of such evidence.

The reactions of fish to substances in solution also have been studied (93) (112) (113) (94) (89) (114) (90) (69) (41) (52) (53). These studies have shown that, under experimental conditions, fishes are able to detect and to avoid lethal concentrations of some toxic pollutants, such as acids and sulfides. However, fishes were not repelled, or even were apparently attracted, by lethal concentrations of many other toxic substances, such as copper sulfate and ammonia (89) (52) (53). Close correspondence between the reactions of fish to water quality differences or gradients under the experimental conditions in the laboratory and under more natural conditions may not be assumed (22). Nevertheless, the experimental results show how the danger to fish from toxic pollutants can be aggravated in the vicinity of sewer outfalls, where mixing of wastes with available diluting water

[3] For example, Gollmar (34), citing Keyes (56), listed "concentrations possibly toxic to fish" of some components of coke and gas plant wastes. Some of these values (for example, 10 p.p.m. of cyanide) are at least 10 to well over 100 times greater than concentrations found to be lethal to various fish by competent investigators.

is incomplete. The ability of fish to recognize and to avoid all harmful conditions has been too often baselessly taken for granted. Inasmuch as the reactions of fish evidently do not reliably indicate the relative toxicity of pollutants, further consideration of reaction tests is deemed outside the scope of this review.

Various alkalies, acids, and inorganic gases (some of which form aqueous solutions which are decidedly acidic or alkaline) are important constituents of many different industrial effluents (including mine drainage). An understanding of their injurious effects on aquatic life is, therefore, of great importance, and these substances will be considered first. Subsequent parts of this review will deal with the toxicity of inorganic salts and other inorganic substances, organic waste constituents, and various types of complex industrial wastes. Most of the very weak organic acids and bases, such as the various tar acids (phenol, cresols, etc.), will be considered later, together with other organic compounds.

The injurious action of some of these substances on fish is largely or wholly external, and is not regarded by some as true toxic action (28). However, the distinction between such external action and the internal toxic action of substances penetrating the body of the fish is not always clear-cut, and is of little practical import. In this review, only substances which are injurious to fish merely by mechanical action, or by causing depletion of dissolved oxygen in the water and consequent suffocation, are not considered under the heading of toxic substances. All other directly injurious substances are so considered.

Strong Alkalies

The resistance of various fresh-water fishes to strong alkalies (that is, sodium, potassium, and calcium hydroxides) in distilled and natural waters has been studied by many investigators (13)(112)(81)(82)(80)(97)(20)(21)(7)(58)(24)(57)(108). Inasmuch as the pH of the experimental solutions was not stated and regulated, the results of most of these studies are of limited value. The initial pH, and consequently, the toxicity of solutions prepared with natural water depend on the dissolved mineral content and buffering capacity of the water, as well as on the amount of alkali added. Some of the tests have been of such brief duration (for example, only 1 hr.) that the results are of questionable significance. In the course of more prolonged tests, the alkaline solutions may have been quite rapidly neutralized by respiratory carbon dioxide produced by the test animals, and otherwise, so that constancy of their composition may not be assumed. Concentrations of the various strong alkalies, which have been reported to be the lowest that were lethal to trout and other fresh-water fishes, in about 1 to 24 hr., in distilled and moderately buffered natural waters, range from 0.0005 N to 0.0025 N. Higher minimal lethal concentrations in hard waters have been recorded.

Some investigators have reported fatal effects of slight alkalinity, and even neutrality, of certain waters on the embryos and fry of trout and yellow perch (44), whitefish larvae (41), and also fully developed fresh-water fishes (112). The injurious or toxic action of these waters was said to be counteracted by the introduction of enough carbon dioxide, or stronger acids, to produce a slightly acid reaction. The nature and the presentation of the data are such that the significance of the results is somewhat obscure, and the conclusions cannot be accepted without question. The possibility that some unknown lethal agents, the action of which varied with the pH of the water, were responsible for the observed mortality was not entirely ruled out. According to Shelford

(92), Wells' (112) criterion of neutrality was erroneous. Hopkins (44) found that trout 4 to 6 months old survived well in alkaline water of pH 7.9 to 8.9 (treated Baltimore city water supply), whereas eggs and fry of trout and perch did not survive at pH values even in the neighborhood of 8.0. The young perch survived, however, when the pH was experimentally lowered to 6.7 by the addition of carbon dioxide. Hopkins concluded that the presence of free carbon dioxide is necessary for survival.

The occurrence of thriving populations of fresh-water fishes, including trout (18)(16), in waters which are normally decidedly alkaline is well-known. Experimental data showing survival and normal development of rainbow trout embryos in very hard, alkaline water without free CO_2 have been reported by Surber (105).[4] Nevertheless, it should be borne in mind that the pH and carbon dioxide tension requirements of embryonic and larval fish may differ markedly from those of the fully developed young and adults. Results of experimental studies of the tolerance of the older fish, which are reviewed here, and the conclusions drawn therefrom, certainly are not necessarily applicable to all stages of the life cycle of the species studied. The need for further detailed study of optimal conditions for development is indicated.

Wiebe (116)(117), experimenting with several pond fishes, found that they usually withstood rapid changes of pH within the range of pH 6.0 to 9.6. Some mortality was observed (for example, of fish which had been exposed to NaOH solutions with pH above 9.0), but its significance is uncertain, as the results of the varied, prolonged, and somewhat random tests apparently were not all checked sufficiently. Stiemke and Eckenfelder (98) reported that the average death point for bluegill sunfish in distilled water to which sodium hydroxide was added at 4-hr. intervals in order to raise the pH gradually, was at pH 10.55. Bandt (5)(6) studied the survival of several species of fish in water with high pH produced and maintained for long periods by keeping the water in contact with blocks of fresh concrete. He concluded that the minimum lethal pH values were 9.2 for trout and perch, and 10.4 to 10.8 for roach, pike, carp, and tench. Having considered the possible role of the various dissolved substances known to be present, Bandt decided that the observed toxicity of the water could be attributed only to the high pH caused by alkaline components leached from the fresh cement.

Powers (71) also attributed rapid mortality of trout placed in soft water in a concrete hatchery pool to alkali leached from the cement. He concluded, however, that the death was caused not by excessive alkalinity or pH of the water (maximum recorded pH 7.69), but by "free alkalinity" or by abnormally low carbon dioxide tension (minimum about 0.06 mm. Hg) to which the fish had been suddenly subjected. Other possibilities, or factors, apparently were overlooked, or were not explored adequately. The fish had just been transported from another hatchery, and the soft water, supplied through galvanized steel pipe,

[4] The reported average pH value (pH 7.7) of this water (having initially an alkalinity of about 265 p.p.m. and much free CO_2), which had been treated with caustic soda, is not strictly compatible with the reported free CO_2 content of 0.0 p.p.m. It is probably only approximate, but in any event a very low CO_2 tension is not indicated. Surber (unpublished manuscript) also found that the water before treatment (pH 7.1) was unfavorable for the incubation of brook trout eggs. The addition of enough caustic soda to remove only part of the free CO_2 made the treated water (pH 7.4 to 7.5; free CO_2 over 10 p.p.m.) even more injurious. The cause of the injury is unknown, but may be related to the extreme hardness of the water. Some successful trout hatcheries have been supplied with water containing much less free CO_2 and with recorded pH well above 7.5.

could conceivably have been contaminated excessively with zinc. Powers' conclusions not having been verified through properly controlled experiments, their validity is doubtful.

It is noteworthy that the survival of trout at pH values well above 9.2 has been reported. Eicher (27) observed mortality of many, but not all trout in a lake where the pH of the water was said to have been above 10.2. The high pH, which was ascribed to natural causes (heavy growth of aquatic vegetation), was believed to have been the cause of the mortality. Eicher also stated that trout survived in a stream where the pH value rose to 9.4, although, according to this author, the observed pH was "easily enough to quickly kill fish fresh from neutral hatchery water." No experimental data were presented, however, to establish the validity of the latter assertion and other conclusions.

Powers (70)(73) and Wiebe *et al.* (119) showed that at high pH values, which probably could be tolerated indefinitely under otherwise favorable conditions, the ability of some marine and fresh-water fishes to utilize oxygen and to survive at low oxygen tensions was impaired.

Sanborn (85) performed some of the most satisfactory experiments designed to test the resistance of fresh-water fishes to alkalies. The tests were of prolonged duration, and the pH values of the experimental solutions were kept constant during some of the tests. This was accomplished by means of constant-flow apparatus, whereby the solutions in the experimental aquaria were renewed continually. The water used as a diluent was tap-water of medium hardness (64 to 80 p.p.m. total hardness, of which 28 to 36 p.p.m. was noncarbonate hardness), with initial pH of 7.2 to 7.6. Unfortunately, only two specimens of each species tested were exposed to each of the experimental concentrations of the chemicals studied, and the method used for determining pH was not stated.

In these tests, young goldfish (*Carassius auratus*), large-mouth bass (*Micropterus salmoides*), and bluegill sunfish (*Lepomis macrochirus*) were used. These fishes were not visibly affected after remaining for 7 days in flowing water to which 50 p.p.m. of either sodium hydroxide or calcium hydroxide had been added, raising the pH to 10.4 and 10.5, respectively. All of these fishes succumbed in 2 to 5 hr., however, at pH 11.1, produced by the addition of 100 p.p.m. of calcium hydroxide to the water. Goldfish died also in 3 to 20 hr. at a constant pH of 10.9, resulting from the addition of 100 p.p.m. of sodium hydroxide. Bass and sunfish were not subjected to the latter test. However, bass died within 10 hr. in a standing solution prepared with sodium hydroxide (100 p.p.m.), the pH value of which was initially 10.9 and decreased gradually during the test.

Sanborn also performed tests with continually renewed solutions of sodium carbonate. Solutions of pH 9.7, 10.1, and 10.6 were prepared by the addition of 100, 200, and 500 p.p.m. Na_2CO_3 to the tap water. Survival for 7 days without apparent injury was observed with goldfish at pH 10.6, with bluegill sunfish at pH 10.1, and with large-mouth bass at pH 9.7. The sunfish and bass succumbed within 11 hr. at pH 10.6, and the bass succumbed at pH 10.1 within 4.5 days. These data indicate that water of high pH due to hydrolysis of added carbonate is at least as harmful as water which has been made equally alkaline by the addition of hydroxide.

Having reviewed the published data, the conclusion is drawn that fully developed fresh-water fishes can withstand pH at least as high as 9.0 for long periods. Much higher pH, well above 10.0, also can be tolerated by the more resistant species in the absence of other harmful conditions. No convincing evidence has been found that equally alkaline solutions of different strong alkalies commonly occurring in

industrial effluents differ markedly in their toxicity. Such differences presumably could result, under some conditions, from peculiar physiological action of the cations involved (for example, toxic action of potassium ions). Apparently, the influence of the cations ordinarily is of minor importance, however. Therefore, the increased hydroxyl ion concentration of water contaminated only with the common strong alkalies is the factor chiefly to be considered when judging the possibility of damage to fish. The subnormal carbon dioxide tensions associated with abnormally high pH values also may be important, but their influence is still uncertain. Further studies are needed to determine whether or not the CO_2 tension is ever a more reliable index of harmful pollution with alkalies than the pH value.

Ammonia and Ammonium Hydroxide

Numerous studies of the toxicity of dissolved ammonia, or ammonium hydroxide, to fish (13)(89)(81)(82)(100)(7)(58)(50)(63)(28)(88)(98) have yielded varying results. The lowest lethal concentrations reported by different investigators were in several instances between 2 and 7 p.p.m. as NH_3, and ranged upward to well over 25 p.p.m., although usually they did not exceed this value. Obviously, the pronounced toxicity of the very dilute solutions of this weak base is not attributable to the alkaline reaction alone.

However, it has long been known, also, that the base is much more harmful than ammonium salts in the same water, and that its toxicity can be reduced or eliminated by the addition of acids (13)(89)(82). Several investigators have noted that the toxicity of ammonium salts, such as the chloride and sulfate, varies with the hardness or the bicarbonate content of the water, being considerably greater in alkaline tap water than in distilled water (113)(91)(35). For example, Grindley (35) found that rainbow trout were affected more rapidly in a solution of ammonium chloride prepared with alkaline tap water and having an ammonium content of 75 p.p.m. as NH_3 (initial pH 7.8), than in a solution prepared with distilled water and having an ammonium content of 3,000 p.p.m. as NH_3 (initial pH 5.4). The average time intervals until the fish lost equilibrium at different concentrations of the salt in varying mixtures of distilled and tap water were determined and plotted, clearly illustrating the above relationship. It is not surprising, therefore, that there is very wide disagreement between the results of investigators who have studied the toxicity of ammonium salts to fishes in different waters (13)(113)(68)(89)(63)(28). Concentrations of NH_4Cl, $(NH_4)_2SO_4$ and NH_4NO_3 ranging from less than 0.001 N to more than 0.05 N have been reported to be near the limits of tolerance of the fishes under various experimental conditions.

McKay and Vars (63) compared the survival time of bullheads in tap water solutions of varying ammonium content, prepared with several ammonium compounds. When the ammonium concentrations of the solutions were approximately equal, ammonium carbonate proved much less toxic than ammonium hydroxide, but more toxic than ammonium acetate and especially ammonium sulfate and ammonium chloride, which tend to form acidic solutions. McKay and Vars (63), Ellis (28), and Grindley (35) observed no pronounced difference between the toxicities of the sulfate and chloride. Other investigators have obtained somewhat different results, which may be ascribable to variations of experimental conditions.

Ellis (28), citing unpublished studies by Ellis and Chipman, pointed out that the toxicity of ammonium compounds depends on the pH of the solutions, increasing with the pH value. He found that it increases "200 per

cent or more between pH 7.4 and pH 8.0." Without detailing the experimental evidence, he stated that the lower limit of toxicity was found to be near 2.5 p.p.m. of ammonia, and that this concentration is harmful even at pH 7.4 to 8.5. He reported also that 2 to 2.5 p.p.m. of ammonia in hard water proved fatal to goldfish and perch in one to four days. The pH value was not stated. When the results of toxicity tests are presented, failure to distinguish clearly between dissolved ammonia, or ammonium hydroxide (as NH_3), and the ammonium radical in solution (also reported as ammonia) is somewhat confusing.

Wuhrmann, Zehender, and Woker (123) discussed and plotted the relationship between pH and the concentration of non-ionic free ammonia, or undissociated ammonium hydroxide ($NH_3 \cdot H_2O$), in ammonium salt solutions of varying concentration. They pointed out that the concentration of the non-ionic ammonia, or ammonium base, increases both with increasing concentration of ammonium radical and with rising pH value, and that it can be derived from the pertinent data. Experiments were performed with a comparatively resistant fish, *Squalius cephalus*. These were exposed to ammonium sulfate solutions of varying concentration, adjusted to different pH values between 7.0 and 9.5. The exposure time required to produce lasting loss of equilibrium was determined. It was shown that there was no obvious and consistent relationship between this time and either the total ammonium content or the pH value. Instead, the time was evidently dependent upon the computed (theoretical) concentration of non-ionic ammonia, or ammonium base. For example, when the latter concentration was between 2 and 3 p.p.m. as NH_3 (in solutions with over-all ammonium concentrations of 10.1, 38.4, and 167 p.p.m. and pH values of 8.84, 8.16, and 7.4, respectively), the time to loss of equilibrium ranged from 330 to 170 min. When the concentration of non-ionic ammonia was increased to 16 to 24 p.p.m. as NH_3, either by increasing the ammonium content of the solutions (without change of pH), or merely by raising the pH value, the time was reduced to 26 to 27 min. The authors expressed the opinion that at pH 7.5 to 8.0 about 10 to 15 p.p.m. of ammonium radical would be required to produce a concentration of the non-ionized base that would be harmful to the more sensitive fishes.

In a more detailed report, Wuhrmann and Woker (124) tabulated and plotted additional data showing the relation between the effective exposure time and the computed concentration of free, molecular ammonia (base) in solutions of varying pH and ammonium sulfate content. They concluded that the toxicity threshold, or minimum acutely toxic concentration of the base, at a temperature of 14° C. and a dissolved oxygen concentration of 9 to 10 p.p.m., is about 1.0 to 1.2 p.p.m. NH_3 for adult *Squalius*. At higher concentrations the fish lost the ability to maintain their position in a current within 6 hr. The corresponding threshold value for rainbow trout fry was estimated to be about 0.3 to 0.4 p.p.m. NH_3, but this conclusion was based on somewhat inadequate and conflicting experimental evidence. Unfortunately, the evaluation of the seemingly exact reported concentrations of molecular ammonia in the test solutions was not detailed and explained fully. A striking synergy, or combined toxic action, of ammonia and cyanide in various experimental mixtures was demonstrated.

Further studies evidently are needed to establish more definitely the minimal lethal concentration of ammonium hydroxide *per se* for various fish species under different conditions. The early investigations are not very helpful in this connection, because the data reported are inadequate. Inasmuch as

the acute toxicity, at least of solutions of ammonium compounds, apparently is attributable largely to the undissociated base (probably because of its distinctive penetrative properties), rather than to the ions present, the concentration of this component in polluted waters is of primary importance. However, it has not been established that ammonium ions have no pronounced influence upon chronic toxicity of solutions of ammonia and ammonium salts. Furthermore, a high concentration of ammonium ions in water which is not initially demonstrably toxic should be regarded as a potential hazard to fish life, if the pH may be subject to considerable fluctuations. Such changes may be due either to natural causes or to intermittent additional pollution with any alkaline wastes.

Acids

The occurrence and prolonged survival of various fresh-water fishes in acid waters with pH values well below 5.0 has been observed repeatedly (11) (49) (28) (23). Dahl (17) observed 80 per cent mortality of very young trout fry in waters acidified with peat to pH 4.7 to 5.4; 10 per cent at pH 5.1 to 5.7; and no mortality at pH 5.4 to 5.9. However, the occurrence of trout in acid bog waters with recorded pH values below 4.7 also has been reported (64) (16) (95). Schäperclaus (86) (87) noted that carp became diseased in acid water at pH 4.8, and tench died after two days at pH 4.6; but tench and pike lived at pH 4.8. He concluded that pH values of 4.8 or lower are injurious to fresh-water fishes. Dyk (23) found that various fresh-water species withstood pH 5.2, and succumbed within 24 to 48 hr. at pH 3.6, but tench survived for 14 days at pH 3.6 to 3.8. It is apparently safe to conclude that, in general, the acidity of waters with pH values above 5.0 can be tolerated indefinitely by most fresh-water fishes, in the absence of other adverse conditions. The suitability of waters with pH near 5.0 for successful reproduction of the more sensitive forms is questionable, but the limits of tolerance for fully developed young and adults of many species may be well below this value.

Ellis (28) studied experimentally the survival of goldfish (*Carassius auratus*) in natural (mostly hard) waters acidified to various pH values with eleven mineral and organic acids found in industrial wastes. His tabulated data reveal no pronounced or clearly significant differences between the minimal lethal hydrogen (hydronium) ion concentrations of waters acidified with sulfuric, hydrochloric, nitric, lactic, citric, oxalic, and tartaric acids. Mortality was always observed within a few hours when the pH values were 3.4 to 4.0 (or lower), whereas none occurred in four days when the pH values were 4.5 to 4.9 (or higher). Ellis attempted to compare the toxicities of these acids, arranging them in order of lethality, as indicated by the minimum pH values, as well as the maximum concentrations (parts per million added to a given hard water), which were tolerated. Judging by the tabulated data, such a comparison was not justifiable, as the number of tests at different pH values within the critical range appears to have been inadequate. Furthermore, some features of the tabulated data indicate that the values compared are not strictly comparable, or that considerable experimental errors were involved. For example, the pH values of solutions containing 143 p.p.m. of sulfuric acid (0.0029 N) and 200 p.p.m. of nitric acid (0.0032 N), prepared with the hard water (pH 7.8), were said to have been pH 3.5 and pH 4.9, respectively. Likewise, a 169 p.p.m. H_2SO_4 solution (0.0034 N) was reported to be more acid than a 750 p.p.m. HNO_3 solution (0.0119 N). Several other such discrepancies were noted.

The results of Ellis' tests with acetic,

benzoic, chromic, and tannic acids indicated that moderately hard waters to which these substances have been added can be decidedly toxic when the pH values are above 5.0. Hard water acidified to pH 5.5 with acetic acid (348 p.p.m.), pH 5.9 with benzoic acid (200 p.p.m.), pH 6.4 with chromic acid (200 p.p.m.), and pH 7.6 with tannic acid (100 p.p.m.) proved lethal within 4 days to some or all of the experimental animals. All higher concentrations tested were invariably lethal, death occurring within 6 hr. at pH 4.6 to 6.4 (depending on the acid) and within 20 hr. at pH 5.0 to 7.3. Unfortunately, the experimental procedures and conditions were not described fully. It was not stated, for example, whether liberated carbon dioxide gas was or was not removed by aeration from the experimental solutions before the introduction of the test animals. Also, Ellis did not show how much the pH values of the solutions deviated from the reported values during the tests. Some of the solutions were continually renewed by means of constant-flow apparatus, but few critical concentrations were tested in this manner. Usually the pH values probably were not perfectly constant, and variations occurring in standing solutions may have been considerable.

Ellis recognized that "it is futile to attempt to designate a given p.p.m. value as marking the lethal point for any particular acid, as the buffer substances and dissolved salts of the water into which acid waste is poured will determine the amount of free acid or hydrogen ions available." He concluded that "as far as the hydrogen ion concentration alone is concerned, the acidity near the magnitude of pH 4.0, regardless of the acid or acid-salt combination producing this acidity, will be lethal to fresh-water fishes if that concentration of acidity be maintained. In concentrations less acid than pH 4.0, the penetrative properties and the lethality of the kation of the acid must be considered, for it may be seen that at any given pH the relative lethality varies with the particular acid involved." Evidently here, and throughout his discussion, Ellis meant to say "anion" instead of "*kation.*" With this correction, the above conclusion appears to be more or less valid. Ellis' discussion of the nature of the lethal action of different acids is interesting, but some of the statements may be somewhat misleading, and are not supported by any experimental evidence. Probably too much emphasis is placed upon the role of different ions involved, minimizing the important role of undissociated acid molecules in solutions of weak acids. The importance of coagulation of mucus and cell proteins of the gill membranes and resulting interference with respiratory exchanges, as a cause of death in acid waters, perhaps is overemphasized. This explanation of the lethal action of dilute (that is, not rapidly lethal) solutions of strong acids (for example, at pH near 4.0) needs verification.

Westfall (115) reported some interesting results bearing on this problem. Tap water acidified to pH 2.6 with sulfuric acid and aerated to remove liberated CO_2 caused the formation of coagulation film on the gills of goldfish. The duration of their survival varied with the dissolved oxygen content of the water. These observations indicate that "coagulation film anoxia" may have been at least partly responsible for the rapid mortality of the fish under the conditions of the experiment (very low pH value), as suggested by Ellis. Corresponding effects were not observed, however, when lactic acid, in a solution of pH 4.0, was the lethal agent. Its lethal action was attributed to internal effects ("acidemia").

It is noteworthy that other authors (92)(119)(107) have attributed (perhaps erroneously) an observed decrease in the ability of fish to extract oxygen at low O_2 tensions in acidified water to increased hydrogen ion concentrations

of the medium. At the moderate pH values involved, coagulation film formation certainly could not have been a factor. However, in the absence of adequate information or of sufficiently convincing evidence to the contrary, it appears that increased carbon dioxide tension, and not lowered pH, may actually have been the factor chiefly responsible for the effects observed by these investigators.

Stiemke and Eckenfelder (98) studied the survival of bluegill sunfish at progressively increasing concentrations of various mineral and organic acids in distilled water. The pH value of the solutions decreased, usually, by only a few tenths of a pH unit at regular intervals. With all of the acids tested—namely, hydrochloric, nitric, sulfuric, phosphoric, acetic, propionic, and lactic acids—the reported average death points (based on 0.5 hr. dosing intervals, or exposure periods) were at pH values below 4.0. They ranged from pH 3.11 to 3.22 for the four mineral acids, and from pH 3.47 to 3.89 for the organic acids. Sulfuric and acetic acid solutions of pH 3.65 and 3.90, respectively, were tolerated for 24 hr. in early tests (in winter). Death points based on 4-hr. dosing intervals, obtained in experiments performed later (in spring), were pH 3.7 to 3.8 for sulfuric, hydrochloric, and nitric acids, and pH 3.95 to 4.04 for acetic and propionic acids. Mixtures of different acids also were tested.

On the basis of the experimental results, the authors formulated and discussed at length an admittedly purely empirical mathematical relationship.[5] Thereby, it was claimed, "it is possible to predict the effect of any concentration or resulting pH of an acid industrial waste on the survival of fish." Although realizing that certain approximations and assumptions involved in the development and application of their method may be subject to basic criticism, the authors believed that it has merit from a practical standpoint. However, the outstanding feature and weakness of their formula is its derivation from the results of tests in which only distilled water was used as a diluent. There is no evidence that its applicability to natural stream waters had been explored or considered. Inasmuch as there are abundant reasons for questioning such applicability, the formula appears to have almost no validity from a practical standpoint. (Some computations made by the present authors in attempting to apply the suggested criterion to ordinary natural waters yielded results which were grossly incompatible with actual observations of other investigators.) The authors admitted that, because of "the toxic nature of some acids, such as hydrocyanic acid, or their poisonous effect on fish" such acids do not follow the proposed criterion without "appropriate corrections," which were not clearly prescribed. They did not explain, however, to what kind of action they attribute the varying lethality of the other acids. Obviously, the authors' claim that, by using the theoretical curves based on their formula, an industry "can quickly determine the maximum reduction of pH that can be tolerated in a stream by discharge of an acid waste without harmful effects on fish" is unjustified and likely to be misleading. However, the experimental data presented have some theoretical value.

Carpenter (12) reported that the minnow *Leuciscus phoxinus* was killed in 7 hr. in distilled water acidified with nitric acid to pH 4.4 and in 27.5 to 28 hr. when the pH was 5.0, but was un-

[5] $(\mathrm{pH})(\log C)^n = N_E$, in which C is the concentration of the acid expressed as p.p.m. $CaCO_3$; n is a constant depending on the type of acid, equal to $(1+a)$ for most acids, where a is the degree of ionization; and N_E is Eckenfelder's number. It was observed that the value of N_E was close to 7.4 at the death point for all the acids tested. Values above 8.4 were said to indicate lethal conditions, while those between 8.4 and 6.2 were said to represent conditions under which survival is doubtful.

affected after more than 3 days when the pH was 5.2. Jones (51) determined the survival time to sticklebacks (*Gasterosteus aculeatus*) in hydrochloric acid solutions of varying pH, prepared with a very soft natural water of high purity and renewed twice daily. He found that the average survival time increased progressively from 65 min. at pH 2.8, to 20 hr. at pH 4.2, 5.5 days at pH 4.8, and 9 days at pH 5.0. The average survival time at pH 5.0 did not differ significantly from that of controls. Jones also found that the average survival time of the fish in different solutions of ferric chloride ($FeCl_3$) did not differ from that in HCl solutions with the same pH value. He concluded that the toxicity of ferric chloride solutions is mainly, if not entirely, due to their acidity. A similar result was obtained with ferrous sulfate ($FeSO_4$), but not with aluminum nitrate and chromium sulfate, the solutions of which were much more toxic than HCl solutions of corresponding pH. Although salts of this nature (or their cations) are in a sense acids, other studies of the toxicity of these substances will be reviewed later, together with studies of other inorganic salts.

Guelyard and Duval (37) studied the survival of sticklebacks (*Gasterosteus aculeatus*) in solutions of varying pH, prepared by adding acids to 0.02 N solutions of their sodium salts (used as buffers and claimed to be harmless to fish) in distilled water. The survival time varied with the pH value and with the nature of the acid tested. For example, death in solutions containing phosphoric, lactic, acetic, and propionic acids occurred after 14 to 17 min. at pH 2.2, 3.2, 4.4, and 4.6 and after 7 to 8 hr. at pH 4.0, 4.4, 5.4, and 5.8, respectively. Because of the nature of the test solutions, the practical value of these results is limited. Macovski and Macovski (61) have presented a theoretical discussion of these data. Gauze and Smaragdova (33) found that optical isomers of tartaric and malic acids in distilled water differed in their toxicity to various freshwater fishes, although no difference of the pH of the solutions of the isomers was detectable when their concentrations were equal.

Shelford (90) reported that flowing (that is, continually renewed) sea water acidified to pH 6.85 with sulfuric acid (39 p.p.m.) was fatal to young herring, *Clupea pallasii*, after 8 hr. Sea water acidified with only 2.3 to 3.7 p.p.m. of sulfurous acid to pH 7.25 to 7.6 was reported to be lethal to the herring in 1 hr. There is some evidence, however, of serious inaccuracy of the observations. The pH value of sea water said to contain only 3.5 to 3.7 p.p.m. H_2SO_3 (determined by iodimetric titration) was reported to be as low as the pH of the same water acidified with 30 p.p.m. H_2SO_4 (that is, pH 7.25, determined colorimetrically). The small amount of H_2SO_3 said to have been added evidently cannot account for the observed depression of the pH value (initially about 8.0). Calcium sulfite and calcium acid sulfite were stated to be nearly as toxic as sulfurous acid in flowing water, and even more toxic than the acid in standing solutions. Details of the experiments with the salts were not reported. Very little free SO_2 or sulfurous acid (undissociated) actually could have been present in the solutions prepared with H_2SO_3 at the high pH values recorded. Observed changes of the toxicity of standing solutions, which were attributed by the author to escape of SO_2 gas, may have been due chiefly to oxidation of sulfites. Shelford reported that viviparous perch, *Cymatogaster aggregatus*, were killed in 5 hr. in flowing sea water acidified with 65 p.p.m. H_2SO_4 to pH 6.3, whereas as little as 3.9 to 4.2 p.p.m. H_2SO_3 proved lethal in 3.5 hr. The flatfish *Psettichthys* was much more resistant to both of these acids. The above results indicate great sensitivity of some marine fishes to re-

duced pH or to increased carbon dioxide tension of acidified sea water. They also indicate pronounced specific toxicity of sulfurous acid and its salts to these fishes, even in somewhat alkaline solutions.

Shelford (89) also reported that 16 to 19 p.p.m. of SO_2 gas dissolved in tap water was the concentration required to kill small sunfish, *Lepomis humilis*, in 1 hr. The pH of the solutions and the exact composition of the water were not stated, but since the water was said to be of high carbonate hardness, the observed mortality probably was not due merely to acidity of the test solutions. The findings of some earlier investigators also indicate pronounced toxicity of sulfur dioxide, or sulfurous acid and its salts, to trout and other fresh-water fishes. To what extent the toxicity varies with the pH value of the solutions is not clear, but there are indications that this factor may be important. Ellis (28), using constant-flow apparatus, found that, at pH 7.6, 1,000 p.p.m. of sodium sulfite (Na_2SO_3) in hard water killed all goldfish in 3 to 72 hr.; 100 p.p.m. killed some goldfish in 96 hr.; and 10 p.p.m. had no effect. The data do not indicate great toxicity of sulfite ions. These results, as well as some similar observations of our own (unpublished), including results of exploratory tests with different fish and varying pH values, are not easily reconciled with some of the earlier pertinent data mentioned above. The need for further investigation is evident.

Brinley (10) and others, as well as Wuhrmann and Woker (124), who reported instructive experiments with fish, have claimed that the toxicity of solutions of cyanides may be ascribed chiefly to the toxic action of undissociated hydrocyanic acid (HCN), decreasing when the pH value is raised. However, Southgate (95) observed no influence of variations of pH between 6.0 and 8.5 on the toxicity of cyanide solutions to trout. Cyanide concentrations as low as 0.05 to 0.2 p.p.m. have been shown to be lethal to some fresh-water fishes in waters of normal pH (96) (54) (28). Hydrocyanic acid obviously is extremely toxic. Inasmuch as the numerous experiments on the toxicity of cyanides to fish usually have involved the use of salts (such as KCN), rather than the acid, they will not be considered further at this time.

Wurtz (125) studied the toxicity of boric acid to several fishes and found it to be slight, extremely high concentrations of this very weak acid being required to produce rapid mortality. In a 6,250-p.p.m. solution a rudd and a roach were dead after 18 hr. and 46 hr., respectively. In a 2 per cent solution, at pH 6.2, a rainbow trout was overcome, but not killed, within 30 min.

Strell (102) compared the toxicity of hydrofluoric and hydrochloric acids to trout, and concluded that the former acid is about twice as toxic as the latter. This difference was attributed to the toxicity of fluoride ions. However, the author's assertion that solutions of equal concentration by weight of these two acids were also of equal "acidity" is obviously erroneous. He determined the acidity of his prepared stock solutions by titration with NaOH, using congo red as an indicator. This indicator is quite unsuitable for the titration of hydrofluoric acid. Actually, the experimental concentrations of the two acids which were said to be equally lethal (that is, 100 mg. HCl and 50 mg. HF per liter) presumably were of nearly equal normality. Because these acids are not equally ionized, the titratable acidity has little physiological significance or value for comparative purposes. The pH values of the test solutions, which apparently were prepared with a natural water of moderate hardness, were not recorded or considered.

Strell also found that a solution containing 5 grams of NaCl per liter of distilled water could be tolerated by the fish, whereas the same concentra-

tion, by weight, of NaF was rapidly lethal. Inasmuch as these solutions were unnecessarily concentrated and were not of equal normality, it appears that the difference of their lethality may have been attributable possibly to a difference of osmotic pressure. However, Ellis (28) found that a considerably lower concentration of sodium fluoride (1,000 p.p.m.) was lethal to goldfish after 12 to 29 hr. in very soft water, and after 60 to 102 hr. in hard water. It is concluded that, although the presence of fluoride ions may be a factor contributing to the toxicity of hydrofluoric acid solutions, its importance in this connection has not been adequately demonstrated by Strell's experiments.

The pH of test solutions not having been recorded, the results of numerous other investigations of the toxicity of mineral and organic acids likewise are of limited value. Some of these are summarized briefly below.

King (57) studied the resistance of different species of trout to hydrochloric acid and other lethal agents (for example, NaOH and CO_2). The lowest concentration of HCl at which all the species were definitely and rapidly affected, dying within 1 hr., was said to have been 0.001 N. King's estimate of the corresponding pH value (3.0) probably is too low, as the solutions apparently were prepared with natural water containing bicarbonates. It has been reported (65) that trout (but not goldfish) appeared to be somewhat less resistant to free sulfuric acid in distilled water than in acidified hard water, from which the liberated CO_2 (which was believed to be injurious) had been removed by aeration. Baird and Duff (3) found that trout were overcome rapidly in solutions of CO_2 (for example, 150 cc. per liter) and in 0.2 N solutions of acetic, butyric, and succinic acids, but were not affected after 1 hr. in such solutions neutralized with lime. Schaut (88) reported that minnows were not affected in 24 hr. by 17 p.p.m. of selenous acid in tap water.

Belding (7) reported the concentrations of hydrochloric acid (10 p.p.m.), sulfuric acid (6.25 p.p.m.), and nitric acid (1.6 p.p.m.) which were lethal to brook trout within 24 hr. in natural water. These data indicate a pronounced difference of the toxicities of chemically equivalent amounts of these strong mineral acids. It is not clear, however, whether or not the data are strictly comparable. Solutions containing 6.25 p.p.m. of tannic acid and 50 p.p.m. of acetic acid also were stated to have been lethal to brook trout in 24 hr.

Steinmann and Surbeck (101) studied the toxicity to trout and other fishes of oxalic, acetic, lactic, and tannic acids in various waters. Oxalic acid was reported to be the most toxic of these acids. Because of their short duration (usually 1 hr.), the tests were not satisfactory. Thus, the toxicity of tannic acid was found to be relatively slight, 2,000 p.p.m. having been lethal and 1,000 p.p.m. not lethal to rainbow trout in 1 hr. at a temperature of 10° C. It is noteworthy that Ellis (28) found that 1,000 p.p.m. of tannic acid killed goldfish only after an exposure of more than 2.5 hr. duration; yet 100 p.p.m. in the same water also proved lethal in less than 21 hr.

Roberts and Jee (80) reported that perch and roach were more sensitive to hydrochloric acid than to sodium hydroxide in distilled water. Only rapidly injurious concentrations were tested for comparative purposes. Rushton (81) (82) made observations on the toxicity of several acids. He reported that 200 p.p.m. of chromic acid killed rainbow trout in about 1 hr. Shelford (89) determined the concentration of benzoic acid (550 to 570 p.p.m.) required to kill small sunfish in 1 hr. in tap water.

Wells (112) and Haempel (39) studied the resistance of different fishes to varying concentrations of sulfuric acid in distilled water and in "neutralized" tap water, respectively. Some of the tests were of prolonged duration (that

is, 1 day or longer). Léger (59) found hydrochloric acid to be about ten times more toxic to trout and minnows than sulfuric acid in distilled water. In hard water the observed difference of toxicity was much less pronounced. These were results of brief (1-hr.) tests only, and they are not in accord with the results of more recent studies. Data presented by Clark and Adams (13) indicate that hydrochloric acid was more toxic than nitric acid in chemically equivalent concentration.

Tabulation and comparison of the data recorded by the above-mentioned investigators, shows that the lowest concentrations of H_2SO_4 and HCl reported to be lethal to fresh-water fishes within 1 to 24 hr. in distilled and soft waters range from about 0.001 N to about 0.0001 N. When data obtained with hard waters are included, the corresponding range extends upward to 0.006 N. With regard to the relative toxicity of the strong mineral acids (including HNO_3), there is much disagreement between the published results of comparative studies; any definite conclusions based on the literature evidently would be premature. The pH of natural water polluted with any one of these acids and with some, but not all, of the weak acids probably is more significant, however, than the amount and kind of acid added.

Carbon Dioxide

The extensive literature dealing with the effects on fish of dissolved, free carbon dioxide, or carbonic acid, cannot be reviewed fully here. Unfortunately, very few experiments of prolonged duration, designed to test the ability of fish to withstand high CO_2 concentrations for long periods of time, have been reported. Concentrations which have no pronounced effect very soon after a sudden or rapid change probably can be tolerated usually for a long time, because some adaptation to increased CO_2 tension is believed to occur (73). For the same reason, mild distress and respiratory abnormalities shown by fish after a rapid increase of free CO_2 should not be regarded as conclusive evidence that a truly harmful concentration has been reached, as they were by Helfer (43) and others. The observed symptoms of intoxication may be transitory and attributable merely to the excessively rapid change of the environment. Nevertheless, CO_2 tensions which are not rapidly lethal sometimes may prove lethal after sufficiently prolonged exposure.

Powers (70) showed that the ability of marine fishes to survive and to extract oxygen at low oxygen tensions was impaired by the addition to the water of moderate amounts of carbon dioxide, whereby the pH value was reduced. Pruthi (76) criticized Powers' work, and presented results of somewhat similar experiments with the stickleback to show that Powers' conclusions were erroneous. However, Pruthi's observations had to do only with the effects of extremely low pH (3.0), which is indicative of the presence of an excess of strong mineral acid. Inasmuch as such acidity is known to be lethal to sticklebacks at any oxygen tension, Pruthi's data are irrelevant, and his criticism of Powers' conclusions is invalid. Pruthi (75) himself reported that sticklebacks died within 45 min. in water acidified to pH 3.0, and within 12 hr. at pH 4.5. He also noted that these fish suffered no harm at CO_2 concentrations not exceeding 10 to 13 cc. per liter (that is, about 20 to 25 p.p.m.).

Other investigators have reported results of experiments similar to those of Powers with fresh-water fish (31) (32) (46) (42) and with marine fish (84). The fish were confined in sealed bottles containing water with a high oxygen content and various amounts of free carbon dioxide. When the fish died, presumably by asphyxiation due to their inability to utilize more oxygen under the existing conditions,[6] the dis-

[6] This interpretation of the cause of death at very rapidly lethal CO_2 tensions may be questioned, however, and needs verification.

solved oxygen content and carbon dioxide content of the water were determined. The data were plotted to show the relation between the CO_2 tension and the O_2 tension at the time of death. Very different curves were obtained with different species. Hart (42), having tested ten Florida fresh-water fish species, listed the average CO_2 tensions at which the fish were unable to reduce the oxygen tension below 80 mm. of mercury (that is, about one-half the saturation value), at temperatures between 12° and 21° C. These values (CO_2 tensions) were 35 mm. of mercury for the gizzard shad, 50 to 70 mm. for three species of the sunfish family and the chubsucker, 91 mm. for the golden shiner, 125 to 159 mm. for three different catfishes, and 195 mm. for the eel. Corresponding values for six marine species studies by Safford (84) ranged from 80 to 290 mm. Hg. The CO_2 tensions at which almost no oxygen could be utilized by the six most sensitive fresh-water species tested by Hart differed very little from those at which the O_2 tension was reduced to 80 mm. Hg.

Early studies of the resistance of various fishes to increasing CO_2 tension (121)(78)(79) also revealed great differences between the species. With the exception of trout, the fishes were said to show pronounced symptoms of intoxication (that is, loss of equilibrium, etc.) only at CO_2 tensions falling within the wide range of demonstrably harmful values indicated above (that is, 35 to 290 mm. Hg). In experiments with rainbow trout, however, Reuss (79) observed pronounced distress at CO_2 concentrations of 50 to 83 p.p.m., or computed CO_2 tensions of about 17 to 28 mm. of mercury. Respiratory disturbances or abnormalities were first observed at concentrations about one-half as great (25 to 32 p.p.m. CO_2).

A strikingly different result was reported by King (57), who stated that free CO_2 concentrations of 200 p.p.m. or less had no visible effect whatever on brown, brook, and rainbow trout. His data also indicate very little influence of free CO_2 concentrations in the neighborhood of 200 p.p.m. upon the ability of trout to utilize oxygen at low tensions. Although the free CO_2 determinations made in connection with these particular experiments cannot be said to be definitely erroneous, their reliability can be reasonably questioned. This assertion is based on the fact that many serious errors have been noted throughout the report. For example half-bound CO_2 and fixed CO_2 were said to be equivalent to phenolphthalein alkalinity and to methyl orange alkalinity, respectively. Also, the phenolphthalein acidity of a solution probably containing uncombined hydrochloric acid was said to be equivalent to its free CO_2 content. A possibility that suggests itself is that all the free CO_2 values reported by this author (p.p.m. free CO_2) may have been actually $CaCO_3$ equivalents, or more than twice the true values. Even greater error may be involved, however.

Fish (30) found that adult Pacific salmon and steelhead trout turned over and sank to the bottom within 90 sec. after a free CO_2 concentration of 200 p.p.m. was attained. Like some of the early investigators, he emphasized the anesthetic or narcotic action of CO_2 on the fish. Gutsell (38) reported that a CO_2 concentration of 28 p.p.m. had no apparent harmful effect on trout after several days, and even 39 p.p.m. CO_2 had no pronounced influence on their resistance to oxygen depletion.

Surber (105) studied the influence of high free CO_2 concentrations on the development of trout. He concluded that concentrations between 55 and 78.5 p.p.m. in hard water, at pH 6.9 to 7.0, caused a decided increase of the losses of eyed eggs and of the number of deformed fry produced. Concentrations up to 43 p.p.m. apparently had no harmful effect. Brook trout fingerlings were not noticeably affected by 51 p.p.m. free CO_2. Hall (41) and Kelley (55) studied the influence of CO_2 on the development of whitefish

and herring, respectively. The embryos of these fish also tolerated a fairly wide range of free CO_2 concentration.

Wells (111) determined the duration of survival of seven kinds of fresh-water fish (3 minnow species, 1 sucker, and 3 species of the sunfish family) in flowing, treated water with various concentrations of free carbon dioxide and dissolved oxygen. When the CO_2 content was 35 to 50 cc. per liter (69 to 98 p.p.m.) and the oxygen content high (8 to 10 cc. per liter), the average survival time ranged from 34.5 to 150 hr. and was less than 4 days for all but one species. When the oxygen content was lower (2 to 3 cc. per liter), the survival time was reduced considerably, averaging 16.6 to 138 hr. It was impossible to find any experimental data or other evidence supporting the statement made by Wells (114) that "at a concentration of 10 cc. per liter carbon dioxide will quickly prove fatal to the more sensitive fishes."

Shelford and Powers (94) reported that 20 cc. of CO_2 per liter (39 p.p.m.) proved fatal to young herring, *Clupea pallasii*, within 160 min. Data reported by Shelford (90) also indicate great sensitivity of this and other marine species to free CO_2 liberated in sea water by the addition of sulfuric acid.

Powers (72)(74) claimed that mortality of fish in nature and in hatcheries sometimes is due to "derangement" caused by exposure alternately to higher and lower CO_2 tensions. According to this author, "fish soon become deranged through compensating at short intervals for different CO_2 tensions" of water bathing their gills, by readjustment of the alkali reserve of their blood. This was said to occur, for example, when fish come to the surface repeatedly, from deeper water with a relatively high CO_2 tension, as they begin to feed at daybreak. However, the above conclusions apparently were based only on indirect and consequently quite unconvincing evidence. They have been disputed by Baker (4), who was unable to verify even the experimental results cited as evidence by Powers. In the absence of more direct experimental evidence of the lethality of CO_2 tension fluctuations to which fish may be exposed in their natural habitat, the validity of Powers' interpretation of his observations must be seriously questioned.

It is concluded that some fish species are very resistant to free CO_2. However, concentrations between 100 and 200 p.p.m. can be rapidly lethal to the more sensitive fresh-water fishes in the presence of dissolved oxygen concentrations which are usually deemed quite adequate. Free CO_2 concentrations between 100 and 50 p.p.m., or even lower, also may be lethal after prolonged exposure, or when associated with an abnormally low, though not ordinarily lethal, oxygen tension. They can also prevent normal development of the young. Some delicate marine species, such as herring, apparently are more susceptible than most of the fresh-water species. Although few investigators have reported the pH values of the experimental CO_2 solutions, there is sufficient evidence that the lethality of such solutions is not due to their acidity. It can be readily shown by computation that CO_2 tensions which have been found to be lethal to sensitive fresh-water fish would be associated with pH values above 5.0 in most natural waters. It can be shown, likewise, that harmful quantities of free CO_2 can be liberated from the combined state (bicarbonates) in sufficiently hard fresh waters by the addition of acids, without reducing the pH to a value as low as 5.0. These conclusions have been confirmed by experimental results (unpublished) obtained in our laboratory. Care should be taken, therefore, to distinguish between the toxic effects of added acids or their salts and the effects of liberated CO_2, which is readily re-

movable by aeration (65). An important property of CO_2 is its ability to penetrate very readily into living tissues, where its effects may be related to its acidic nature, but are largely independent of the pH of the external medium (47)(48).

Chlorine and Cyanogen Chloride

The extreme toxicity to fish of free chlorine, or of hypochlorous acid, has long been recognized (120). Taylor and James (106) reported that 0.3 p.p.m. of free chlorine killed rainbow trout in 2 hr., and that 0.25 p.p.m. proved fatal to fingerling trout in 4 to 5 hr., but had no effect on goldfish in 42 hr. It has been reported also more recently (109) that free chlorine concentrations above 0.3 p.p.m. were found to be very toxic to trout, and concentrations between 0.2 and 0.3 p.p.m. were somewhat toxic.

Ebeling and Schräder (26) and Ebeling (25) reported results of numerous and varied experiments designed to test the resistance of many different kinds of fish to free or active chlorine in aquaria, and also in larger tanks and ponds under more nearly natural conditions. The residual chlorine content of the slightly alkaline water was readjusted from time to time during the prolonged tests by the addition of chlorine gas, but nevertheless fluctuated considerably. The fish held in ponds or tanks appeared to be somewhat more resistant than those held in aquaria. Perhaps they were not actually exposed to the concentrations reported. Eels and tench were found to be most resistant, withstanding a residual chlorine concentration of about 1 p.p.m. for long periods. Some carp, also, were still alive at this concentration after 100 hr. Other species were less tolerant, trout and pike dying at this concentration (1 p.p.m.) in 40 hr. or less. Of eight carp held in water with a chlorine content of about 0.15 to 0.2 p.p.m. and at a temperature of 4° to 5° C., two died after more than 12 to 16 days. No carp were killed by this concentration at higher temperatures (above 10° C.). The authors decided that chlorine is most harmful at low temperatures, but the evidence presented is inconclusive. Mortality of goldfish and other coarse fish in the presence of 1 p.p.m. of free chlorine has been reported also by Ellis (28), Zimmerman and Berg (126) and Davis (19). Gromov (36) claimed that 0.5 to 1.0 p.p.m. of chlorine could be tolerated by the mosquito fish *Gambusia*, but 2 p.p.m. killed some of these fish on the second day, and 3 p.p.m. caused at least 50 per cent mortality.

Some of the residual chlorine detected by investigators in their experimental solutions probably was present as chloramine, rather than as free chlorine. A very small amount of ammonia could combine with the chlorine to form chloramine. Coventry, Shelford, and Miller (15) found chloramine to be very toxic to various fresh-water fishes. They reported that chloramine concentrations of 0.76 to 1.2 p.p.m., presumably expressed as chlorine, were fatal to hardy minnows, carp, and bullheads; 0.4 p.p.m. killed trout, sunfish, and some bullheads; and even 0.05 to 0.06 p.p.m. proved fatal to trout fry in 48 hr. The experiments were not described fully. In the absence of strictly comparable data, the toxicity to fish of free chlorine and that of chloramine cannot be accurately compared, but apparently there is no very great difference.

The toxicity of hypochlorites, bleaching powder ("chloride of lime"), and similar products apparently depends on the available chlorine content. Evaluations of their toxicity (83) (9), without determination of available and residual chlorine, consequently have little significance. Hubbs (45) attributed the toxicity to fish of solutions of free chlorine and hypochlorites, as well as ozone and hydrogen peroxide, to the presence and action of nascent

oxygen. This interesting interpretation involves debatable theoretical questions of little practical import.

Chlorine may combine with relatively nontoxic components of wastes to form toxic compounds which, unlike chloramine, are not detectable by chemical tests for residual chlorine, such as the ortho-tolidine test. Schaut (88) noted that chlorination of a dilute, non-lethal solution of potassium thiocyanate (KCNS), sufficient to satisfy the chlorine demand, made this solution extremely toxic to minnows. This was attributed by the author to the formation of cyanide. The thiocyanate was said to be a constituent of gas-house waste liquor.

Allen, Blezard, and Wheatland (1) (2) rediscovered the above phenomenon when they observed that chlorination of certain relatively nontoxic sewage works effluents with a chlorine dose less than the chlorine demand resulted in great toxicity of the treated effluents to rainbow trout. These effluents were found to be derived from sewage to which gas liquor had been admitted. Dilute gas liquor was also found to be much more toxic after chlorination than before. The toxicity of these liquids was evaluated by determining how soon the fish immersed therein lost their balance and turned over, in the presence of ample dissolved oxygen. Further investigation showed that thiocyanate was the constituent of gas liquor which reacted instantaneously with the chlorine to form an exceedingly toxic substance, and that this principal toxic product apparently was cyanogen chloride (CNCl):

$$KCNS + 4Cl_2 + 4H_2O \rightarrow CNCl + KCl + H_2SO_4 + 6HCl$$

The quantity of cyanogen chloride formed was found by these authors to depend on the relative proportions of thiocyanate and added chlorine and also on other factors, such as the presence of interfering substances which compete for the chlorine. Aeration of some solutions containing CNCl eventually caused elimination of their toxicity by physical displacement of the gas, but did not entirely eliminate the toxicity of chlorinated effluents derived from sewage mixed with gas liquor. The residual toxicity evidently was due to some nonvolatile toxic substances formed by reaction of chlorine with constituents other than thiocyanate. The relation between the concentration of cyanogen chloride solutions and their toxicity to trout was carefully determined and plotted. Concentrations between 0.10 and 0.15 p.p.m. caused the fish to turn over in less than 1 hr. at a temperature of 17° to 20° C. The minimal lethal concentration evidently was somewhat less than 0.1 p.p.m.

Hydrogen Sulfide

The great toxicity to fish of dissolved hydrogen sulfide gas, or hydrosulfuric acid, and of sulfides generally, has long been known. Concentrations of the gas below 10 p.p.m. (mostly about 1 to 6 p.p.m.) have been reported to be lethal to sunfish, trout, suckers, minnows, some goldfish, and carp (89)(7)(8)(58)(103)(28)(88)(108). Inasmuch as other sulfides (such as Na_2S) are more or less hydrolyzed in solution, yielding hydrogen sulfide, their toxicity also will be discussed here.

Longwell and Pentelow (60) found that the toxicity of a sodium sulfide solution to brown trout was influenced markedly by variations of pH. The duration of exposure until the fish turned over was increased fifteen-fold by raising the pH from 7.5 to 9.0, and was reduced markedly at lower pH values. The authors concluded that the toxicity is increased (when the pH value is lowered) by the formation of hydrogen sulfide. They also determined and plotted the relation between the reciprocal of the effective exposure time and the sulfide concentration at approximately constant pH of 6.9 to 7.6. The threshold sulfide concentra-

tion which could be tolerated indefinitely under the conditions of the experiment was then estimated by extrapolation to be near 0.6 p.p.m. (as S).

This value corresponds closely with the concentration of H_2S reported by Belding (7)(8) to be lethal to brook trout within 24 hr. (at unspecified pH); namely, 0.86 p.p.m. (0.81 p.p.m. as S). Suckers, aquarium goldfish, and carp were found to be more resistant, the reported lethal concentrations ranging from 3.8 to 6.2 p.p.m. Wild goldfish were still more resistant. Belding (8) also found that temperature has an important influence on the resistance of fish to H_2S, which was markedly increased at low temperatures.

Dodero (20)(21) found the minimum lethal concentration of Na_2S in distilled water, based on 1-hr. tests with brown and rainbow trout and the minnow *Phoxinus*, to be 2 p.p.m. (0.82 p.p.m. as S). However, the minimum lethal concentration in a hard water was reported to be 50 p.p.m. Na_2S (20.5 p.p.m. as S). The limits of apparently harmless concentration in distilled water and hard water were said to be about 0.8 p.p.m. and 40 p.p.m. Na_2S, respectively. These observations apparently are in agreement with the finding of Longwell and Pentelow concerning the influence of pH, although the pH values of the solutions were not reported. The minimum lethal concentrations of ammonium sulfide, $(NH_4)_2S$, were reported to be 0.2 p.p.m. in distilled water, and 2 to 5 p.p.m. in hard water.

Kreitmann (58) reported that for rainbow trout the minimum lethal concentration of hydrogen sulfide, based also on 1-hr. tests only, was somewhat greater in distilled water (3 p.p.m. H_2S) than in hard, alkaline water (2 p.p.m. H_2S). Concentrations about one-tenth as great were said to cause discomfort. Ammonium sulfide $(NH_4)_2S$, was reported to be less toxic, and ammonium hydrosulfide (NH_4HS) about as toxic as H_2S, or even more toxic. There is apparent disagreement between these results and those of Longwell and Pentelow (60) and Dodero (20)(21).

Ellis (28) reported that some goldfish were killed within 96 hr. by 100 p.p.m. of $(NH_4)_2S$ (at pH 7.8) and by 10 p.p.m. of H_2S (at pH 7.6) in flowing, continually renewed solutions prepared with hard water. He found that 100 p.p.m. of H_2S (at pH 7.3) killed all the goldfish only after 3 to 4 hr. Van Horn *et al.* (108) reported that the minimum concentrations of H_2S and Na_2S in a relatively hard water (with total alkalinity of 140 to 160 p.p.m. and initial pH 7.6 to 7.8) which were lethal to certain minnows (*Notropis* spp.) were about 1 p.p.m. and 3 p.p.m., respectively. Only standing solutions, with not less than 4 p.p.m. dissolved oxygen, were tested, and the tests were continued for 5 days. Schaut (88) observed 50 per cent mortality of minnows within 24 hr. in standing water containing initially 5 p.p.m. H_2S. However, he reported that the H_2S content decreased to 1.4 p.p.m. and the dissolved oxygen content fell to 24 per cent of saturation (at about 80° F.) during the test. An initial H_2S concentration of 6 p.p.m. killed all the fish in 24 hr., whereas 4 p.p.m. had no effect. Shelford and Powers (94) noted the pronounced toxicity of H_2S to some marine fishes.

Because of the lack of sufficient pertinent data (pH values, etc.), and for other reasons, the varying results of the reported studies cannot all be readily evaluated and interpreted. It is noteworthy that hydrogen sulfide not only may escape from experimental solutions, but also is gradually decomposed through oxidation, yielding colloidal sulfur. It is concluded that hydrogen sulfide can be toxic to some fresh-water fish in concentrations well below 1 p.p.m. The pronounced toxicity of solutions of sulfides in general may be attributable largely to the

toxic action of H_2S, varying with the pH and with the tension of this gas in the solutions.

Miscellaneous Inorganic Gases

Wells (114) found that 1.2 cc. per liter (1.5 p.p.m.) of carbon monoxide in flowing tap water killed two kinds of minnow in 60 to 115 min., and two kinds of sunfish in 340 to 370 min. The black bullhead was killed only after an exposure of nearly 10 hr. to a CO concentration of 11.7 cc. per liter (14.6 p.p.m.). The concentration required to kill the sunfish, *Lepomis humilis*, in about 1 hr. was reported by Wells to be 6 cc. per liter, but was said by Shelford (89) to be 16 cc. per liter, or 75 p.p.m. (?). One of the latter two values evidently is erroneous, as 16 cc. CO per liter equals 20 p.p.m. The results of the brief tests are not very instructive. Nicloux (66) found that hardy fish could live for some time after their blood had been completely poisoned with carbon monoxide. Nevertheless, the great toxicity of this gas is clearly indicated.

The toxicity of sulfur dioxide (SO_2), which forms sulfurous acid when dissolved in water, already has been considered in connection with that of other acids. Kreitmann (58) found that phosphine (PH_3) in concentrations exceeding 3.6 p.p.m. is toxic to rainbow trout in hard water. The duration of his tests was only 1 hr. Hubbs (45) reported that ozone was lethal to various fresh-water fish in concentrations well below 1 p.p.m., and even as low as 0.1 p.p.m.

Wiebe and McGavock (118) found that species of the sunfish family and trout withstood prolonged exposure to abnormally high concentrations of dissolved oxygen (20 to 34 p.p.m.) without apparent harm. Wiebe (117) also reported that fishes were not affected by more than 40 p.p.m. of dissolved oxygen, and showed increased resistance to high pH in water supersaturated with oxygen. Harmful and fatal effects on fish of water with a large excess of dissolved oxygen have been reported, however, by other investigators (40)(122). The significance of some of these observations is not entirely clear, and is not of sufficient importance to be discussed fully here.

The occurrence of fatal "gas bubble disease" of fish (that is, formation of gas bubbles in the blood vessels and other tissues) in water supersaturated with atmospheric gases has long been known. Presumably it occurs usually when the sum of the tensions of the individual gases dissolved in the body fluids is excessive, in relation to the atmospheric and hydrostatic pressure. It may not be attributable entirely to any single gas, although inert nitrogen has been frequently believed to be chiefly responsible. Engelhorn (29) determined the composition of bubbles formed in fish with artificially produced gas bubble disease. It was found to vary with, and to be initially similar to, the composition of the different mixtures of atmospheric gases with which the water and body fluids had been charged under pressure. The percentage of oxygen decreased with time, however, whereas that of nitrogen increased. Woodbury's (122) supposition that bubbles of oxygen only occurred in fish dying in water in which a rich plant growth caused extreme supersaturation with oxygen is not supported by any evidence. Some conclusions of these and earlier investigators concerning the probable cause of gas bubble formation also appear to be theoretically unsound, or questionable. Further studies have been undertaken.

Summary and Conclusions

1. It appears that, under otherwise favorable conditions, pH values above 5.0 and ranging upward to pH 9.0, at least, are not lethal for most fully developed fresh-water fishes. Much more extreme pH values, perhaps below 4.0 and well above 10.0, also can be tol-

erated indefinitely by resistant species. However, regardless of the nature of acid or alkaline wastes responsible, such extreme conditions, associated with industrial pollution, are evidently undesirable and hazardous for fish life in waters which are not naturally so acid or alkaline.

2. None of the strong alkalies which are important as industrial wastes (that is, NaOH, $Ca(OH)_2$, and KOH) has been clearly shown to be lethal to fully developed fish in natural fresh waters when its concentration is insufficient to raise the pH well above 9.0. Interference with normal development and other damage to fish life sometimes may occur, however, at lower pH values.

3. Solutions of ammonia, or ammonium hydroxide, and also of ammonium salts, prepared with natural waters, can be very toxic to fish even when the pH is not very high (that is, below pH 9). The toxicity of these solutions evidently is dependent largely, if not entirely, on the concentration of the undissociated base, which increases with the pH value, as well as with the over-all ammonium content. A concentration of the non-ionic free ammonia, or ammonium base, of 1.2 to 3 p.p.m. (as NH_3) has been reported to be quite rapidly and uniformly toxic to a relatively hardy species in solutions of varying pH and ammonium ion content. Several investigators have reported that the addition of only 2 to 7 p.p.m. of ammonia (as NH_3) to certain waters proved lethal to some fish.

4. The common strong mineral acids (that is, H_2SO_4, HCl, and HNO_3), and also phosphoric acid (H_3PO_4) and some moderately weak organic acids (for example, lactic, citric, tartaric, and oxalic acids), apparently can be directly lethal to fully developed fish in most natural fresh waters only when the pH is reduced thereby to about 5.0 or lower (see, however, paragraph 6 below). Differences between the toxicities of chemically equivalent concentrations of the strong acids, which have been variously reported, may be attributed to synergetic action of the acid anions, but are probably of minor importance from a practical standpoint. The resistance of sensitive species to these acids, and especially to the organic acids mentioned above, in relation to pH and other factors (for example, the calcium content of the water) has not yet been adequately investigated, however.

5. A number of weak inorganic and organic acids can impart to some waters pronounced toxicity for fresh-water fish without lowering the pH to a value as low as 5.0. The toxicity under these conditions is attributable chiefly to the undissociated acid or acid gas in solution, or to the anions or salts of the acid involved. This group of acids includes hydrosulfuric, hypochlorous, hydrocyanic, carbonic, chromic, tannic, and boric acids, and probably also sulfurous, benzoic, acetic, and propionic acids. It may possibly include also hydrofluoric and oxalic acids, but adequate evidence is lacking. The pH value alone may not be regarded as a reliable index of dangerous pollution of water with one of the acids of this group. Both the concentration and the pH of the solution usually must be considered. Some of these acids (particularly the first three mentioned) are lethal in very low concentrations, whereas the toxicity of others (for example, boric acid) is relatively slight. Much additional information concerning the toxicity of these acids and their salts, in relation to pH and the extent of ionization, and so forth, is needed.

6. The susceptibility of different species of fish to the lethal action of free carbon dioxide varies greatly. Sensitive fresh-water species may succumb rapidly at free CO_2 concentrations between 100 and 200 p.p.m. in the presence of much dissolved oxygen. Lower concentrations (100 to 50 p.p.m., or less) may be lethal after prolonged

exposure, or may interfere with the utilization of oxygen at low tensions and with normal development. The amount of carbon dioxide liberated by the reaction of any sufficiently strong acid with dissolved carbonates and bicarbonates in some hard, natural waters can be lethal to sensitive fish. The resulting mortality of fish can occur at a pH value which is not itself demonstrably harmful (for example, above pH 5.0).

7. Solutions of hydrogen sulfide (as well as of other sulfides), free chlorine, cyanogen chloride, carbon monoxide, and ozone all are extremely toxic to fish. All of these gases have been reported to be lethal to sensitive fish, at least in some waters, in concentrations near 1 p.p.m. or less, and some may be lethal in concentrations below 0.1 p.p.m. The presence in polluted waters of more than a trace of any of these substances evidently should be regarded as a possible hazard to fish life. Chlorine present as chloramine apparently is about as toxic as free chlorine, if not more toxic. Available evidence indicates that about 0.05 to 0.2 p.p.m. of available chlorine and 0.5 to 1.0 p.p.m. of hydrogen sulfide and other dissolved sulfides (as S) may be critical concentrations for the more sensitive fishes under average water quality conditions. Cyanogen chloride and other highly toxic compounds may be formed when some relatively harmless components of industrial wastes (such as KCNS) react with chlorine, leaving no detectable chlorine residual. Phosphine and sulfur dioxide also have been reported to be very toxic to fish.

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FIFTH PURDUE INDUSTRIAL WASTE CONFERENCE PROCEEDINGS AVAILABLE

The Purdue University Engineering Extension Department has made available a 430-page bulletin covering the 43 papers presented at the Fifth Industrial Waste Conference, held at Purdue University, November 29–30, 1949. Subjects covered by the papers include general discussions of industrial waste programs at both the national and regional levels, as well as specific phases of cyanide, gas, oil emulsion, food processing, anti-biotic, distillery, meat packing, brewery, chemical, plating, petroleum industry, acid, pickling liquor, paper and pulp, soap manufacturing, and dairy industry wastes.

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Requests for the bulletin should be directed to Dean W. A. Knapp, Executive Building, Purdue University, Lafayette, Ind., enclosing check payable to Purdue University.

Stream Pollution

STREAM QUALITY OBJECTIVES *

By M. LeBosquet, Jr.

Sanitary Engineer Director, Environmental Health Center, U.S.P.H.S., Cincinnati, Ohio

Water pollution control programs are undertaken for the purpose of restoring the waters to conditions suitable for certain uses, or to maintain water quality suitable for such uses. Water resources attract population and industry, and it is inevitable that streams will be used for disposal of drainage waters and liquid wastes as well as for water supply, recreation, industry, and commerce. The use of streams for disposal of sewage and other liquid wastes results necessarily in some degree of pollution of the receiving waters. Although such pollution cannot be entirely prevented or eliminated, its effects usually may be kept within reasonable bounds by abatement measures such as treatment applied to sewage and treatment or other methods applied to industrial wastes.

The degree of pollution abatement is most logically determined by technical requirements to preserve the water quality for appropriate uses, with due regard to the rights and convenience of the public and riparian owners. It is entirely uneconomical and inequitable that the requirements for pollution abatement be determined otherwise. The costs of construction and operation of abatement facilities are appreciable and should not be burdened upon our public tax system or industrial economy, except to the extent necessary.

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A State Responsibility

The decision as to how far pollution abatement should go is definitely a matter for State consideration. Public Law 845, the Federal water pollution control act, states "It is hereby declared to be the policy of Congress to recognize, preserve, and protect the primary responsibilities and rights of the States in controlling water pollution." Certainly, in the case of State programs, the responsibility for determining degree of pollution abatement belongs to the State. In cases where an interstate agency has jurisdiction, the decision on degree of pollution abatement is the concensus of the States involved. In the case of action under the Federal water pollution control act, State consent and presumably State agreement as to degree of pollution abatement are necessary before action is legally possible. Even in the case involving treaty obligations between Canada and the United States, the International Joint Commission is guided by a Board of Technical Advisers, and the objectives recommended are agreed to by the board member representatives of the States and Canadian Provinces.

In the present discussion, the word "objective" rather than "standard" has been used. The word "objective" denotes a desirable end to be reached, but can be interpreted as an eventual accomplishment, not necessarily immediate. In other words, tolerance can be granted when necessary. In in-

dividual pollution situations involving industrial wastes, it may be necessary to accept less than a wholly satisfactory abatement program pending solution of technical and financial problems. As long as an ultimate goal beckons and abatement efforts continue, experience has shown that ingenuity, a proven characteristic of industry, will before long find a solution. On the other hand, the word "standard" implies something fixed and also something that must be met, and soon. It might be charged that specific high standards were unreasonable and could not be met by existing methods. Much less objection would be raised in the case of a high objective. It is of interest to note that the International Joint Commission, in its consideration of pollution of international boundary waters, uses the word "objective" in establishing the requirements for pollution abatement. Similarly, the Ohio River Valley Water Sanitation Commission, in establishing degrees of treatment in the Cincinnati Pool, also uses the word "objective."

Stream Quality Objectives *vs.* Effluent Requirements

In the operation of water pollution abatement programs, use has been made for administrative guidance of, first, water quality objectives applying to stream waters, and, second, effluent requirements applying to sewage and waste effluents. In the majority of cases in the United States in which objectives have been officially promulgated, such objectives have pertained to the quality of receiving waters as related to requirements for various uses such as bathing, water supply, sanitary purposes, maintenance of fish life, etc. The objectives have often been supplemented by a classification of streams into stretches where certain of the water quality criteria would uniformly apply and where uniform specific requirements would be in force.

There has been some degree of controversy over the merits of stream water objectives *vs.* effluent requirements in water pollution abatement programs. However, there has been little fundamental difference in actual operation, as the effluent requirements have usually been based on stream water quality objectives. For ease of program administration, the effluent requirement approach has much to recommend it. However, it should be recognized as an administrative device and not represented as the basic objective or criterion. Thus, the logical control procedure would set forth the desired stream water quality in a given area and, consistent therewith, the necessary effluent requirements for wastes discharged to such waters. This procedure is logical and provides the administrative advantages associated with the use of effluent requirements. It will be noted in using this combined method that the stream quality objective can be established as a foundation and not changed over a period of years. It may be necessary to revise the secondary effluent requirements from time to time because of unforeseen population growth or increase in industrial waste discharge because of growth or new industries. Again using the dual approach, the governing stream quality objective can be given formal status as a regulation or other official adoption. The necessary effluent quality requirement to reach the objective can then be stated as an administrative opinion, thus having less weight than the fundamental or primary requirement.

In setting a stream quality objective, it is necessary to recognize an initial period of mixing. If a sample is collected in the river at a point that is actually in the outlet stream from a sewer, an unsatisfactory sample might well result. To provide for a mixing period, the International Joint Commission specifies the quality "at any point in these waters following initial

dilution." Similarly, New York proposals specify water quality in "the receiving waters after opportunity for reasonable dilution and mixture with the wastes discharge thereto." It is difficult to specify exactly what the distance should be. Certainly the mixing distance in a small stream is less than in a large stream. Should an important water use be close to a sewer outfall, special mixing might be necessary, as from multiple outlets.

In advocating a basic stream quality objective, it is assumed that the sewage or wastes will mix with the stream water to a degree that the reduced concentrations are not objectionable. Exceptions might be made, therefore, where this assumption is not correct, such as the case of settleable solids that accumulate on the stream bed, or oils and other floating substances which rise to the top and are concentrated by wind or other influences to cause objectionable conditions. There is justification, therefore, for making exceptions to the basic stream quality objective, such as in the two cases cited.

Critical Low Flows

In the design of treatment measures or in the specification of degrees of pollution abatement, it is necessary to determine or define critical low flows under which the objective stream quality will be attained. It would be uneconomical to design pollution abatement works for the lowest flow of record as, for example, for a drought occurring once in 50 years. At the other extreme, a design that would fail to meet objectives once in 2 years would generally not be considered satisfactory. The definition of the critical low flow will normally be between these two extremes.

In selecting a design flow, consideration must be given to the consequences of failure of pollution abatement measures. It may be that a high objective has been selected and partial failure to meet the objective may not cause great damage. Normally, such a failure would not be complete. In other words, if fish life is being protected, a failure would not necessarily mean that all fish life would be destroyed. A failure might mean simply that fish may be distressed over a few hours or may be driven temporarily from a limited stretch of the river. For example, if 4.0 p.p.m. is taken as a dissolved oxygen objective, it is conceivable that oxygen might drop to 3 p.p.m. or even 2 p.p.m. over a limited stretch of stream for a few hours on a critical summer night without damaging fish life.

Typical Examples

There have been a number of cases where advantageous use has been made of water quality objectives. These objectives—sometimes called standards—have varied in status from a list of limitations set forth for purposes of discussion to actual inclusion as a fundamental regulation covering an abatement program.

In October, 1949, the International Joint Commission adopted (1) a set of "objectives for boundary waters quality control." Many of the objectives are stated in general terms, but a few figures are set forth. These are uniformly qualified with the words "adequate protection *should* be provided if . . ." These objectives follow the procedure of establishing a primary stream quality objective followed by a secondary qualified statement of effluent quality under which the objective "quality in the receiving waters will *probably* be attained." It is interesting to note in these objectives that a figure for oils in effluents is specified, but no figure is specified for oils in the receiving waters. On the other hand, a threshold odor in the receiving waters due to pollution is specified but no threshold odor is specified in the effluent. In summary, the

specific figures qualified as described above are as follows:

Determination	Stream Water Quality Objective Which Should Provide Adequate Protection for Uses Specified	Effluent Requirement Which Will Probably Attain Water Quality in Stream Following Initial Dilution
Phenol or phenolic equivalent	5 p.p.b.	20 p.p.b.
pH	6.7 to 8.5	5.5 to 10.6
Iron	0.3 p.p.m.	17 p.p.m.
Threshold odor number	8 due to added material	Not specified
Oil (by extraction)	Not specified	15 p.p.m.

In the case of the International Joint Commission activity, it will be noted that limitations were placed on phenols and on oils. It was felt that "Standard Methods" (2) required supplementing in regard to the phenol determination. During hearings which discussed the oil objective, certain of the industries on the boundary waters asked for a specific definition of "oils." For these two reasons it was found necessary in the case of the boundary waters to supplement the statement of objective with a statement of analytical methods. Normally this would not be necessary as "Standard Methods" furnishes adequate definition of what is meant by the various constituents in natural waters.

One of the strongest treatment specifications is written into the Ohio River Valley Water Sanitation Compact and thus is a basic part of the law. This specification deals with solids, the exact wording providing for "substantially complete removal of settleable solids, and the removal of not less than 45 per cent of the total suspended solids." There is also a provision for higher degrees of treatment when determined to be necessary by the Commission.

In January, 1949, the Ohio River Valley Water Sanitation Commission was called upon to set a degree of treatment for organic wastes in the Ohio River in the vicinity of Cincinnati, commonly referred to as the Cincinnati Pool. This particular objective (3), which involved dissolved oxygen, is of interest in that it was rather carefully defined, the exact wording being as follows:

> For purposes of treatment design, a water quality objective has been taken as 4.0 parts per million of dissolved oxygen at the bottom of the oxygen sag in the Ohio River below Cincinnati. This figure is taken as a daily minimum as measured by the average of three samples taken on a range across the stream, one sample of which is at midstream and the other two of which are at the quarter points. It is expected that the dissolved oxygen at one or two of the points on the range may be below the specified figure. However, it is expected that oxygen results on ranges above and below the bottom of the sag will be above the specified figure.

In the case of the Cincinnati Pool, the wording of the April, 1949, action by the Commission is of interest in that the degree of treatment is tied in rather definitely with the stream quality objective. This wording is as follows:

> Reduction by 65 per cent of the biochemical oxygen demand of organic wastes, subject, however, to the limitation that whenever conditions permit, such lesser degree of reduction, but not lower than 35 per cent, may be applied to such wastes if as a result there will be no impairment in the Cincinnati Pool of a water quality standard of 4.0 parts per million of dissolved oxygen at the bottom of the oxygen sag in the Ohio River below Cincinnati.

Under the new water pollution law of the State of New York, a "Water Classification Standard System" for waters of the State is being prepared (4). The preliminary proposals for this system have been drafted and a series of hearings have been held, the last of which was in Syracuse, N. Y., on June 29, 1950. This interesting

development has resulted from a law which requires the setting up of the system. The legal requirement received the strong support of industry and reflects the desire of industry to have rather specific information as to what might be required of it. In the present proposal for New York State, there are seven classes of fresh water, four classes of salt water, and two classes of ground water. This is one of the most elaborate systems that has been proposed in recent years.

The State of Indiana provides by regulation for objectives in the form of a definition of polluted stream conditions (5). The regulation adopted by the Indiana Stream Pollution Control Board November 8, 1945, contains five criteria, any one of which would indicate a polluted condition:

1. Injurious floating material and oils.
2. Objectionable sludge banks.
3. Materials adversely affecting public health, fish life, animals, and plant life.
4. Generally dissolved oxygen below 50 per cent saturation. Temporary dissolved oxygen below 50 per cent saturation, injurious to fish life. Temporary dissolved oxygen below 25 per cent saturation.
5. Coliforms over 1,000 per 100 ml. (MPN) in bathing waters. Coliforms over 5,000 per 100 ml. (MPN) in vicinity of water intakes.

From a legal standpoint, the reasonableness and legality of the regulations can be established at the start of the program, and thereafter evidence collected for action against a polluter is aimed principally to show a specific violation of one or more sections of the regulation. The regulation is reported to have served as a very useful tool in the abatement of pollution in Indiana.

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MOBILE LABORATORY SURVEY OF THE MIAMI RIVER*

By Bruce M. McDill

Engineer in Charge, Water Pollution Control, Ohio Department of Health, Columbus, Ohio

Procurement of a mobile laboratory unit by the Sanitary Engineering Division of the Ohio Department of Health in March, 1949, definitely made possible an increased tempo in activities pertaining to the water pollution control program. From the standpoint of popular opinion as reflected in recent state, interstate, and federal legislation, the procurement of this equipment has been considered timely. Notwithstanding the difficulties encountered in obtaining and organizing personnel within allowable budget requirements, the accomplishments of the first year's operation have been gratifying.

Designed by the sanitary engineering staff under the supervision of F. H. Waring, chief engineer, and built by John J. Mohler and Associates, Peoria, Ill., the unit comprises a 25-ft. trailer (Figure 1). A station wagon, which also serves for collection of samples and as a crew carrier, is used as a tow car (Figure 2). Contained in the trailer unit are laboratory equipment and supplies (Figure 3) sufficient to make all usually required chemical, bacteriological, and biological examinations. The items of equipment range from delicate balances to large units for incubation and refrigeration. Standard water and electrical connections have been provided so as to obtain the respective services from a selected premise. Otherwise, the unit is self-contained for "on the spot" studies.

First Year's Operation

In the period from April 1 to December 31, 1949, the mobile laboratory was used on 13 special sewage and industrial wastes problems and on one complete river drainage survey. The special problems involved performance tests on sewage and industrial wastes treatment plants, evaluations of industrial wastes as water pollutants, and participation with the Ohio River Valley Water Sanitation Commission and with industry on research studies related to the destruction of phenols and phenol derivatives characteristic of by-product coke plant wastes. The complete river basin survey was that of the Miami River.

Experience has been that efficient operation of the laboratory requires an average field crew of five assistant engineers and engineering aides. Besides the actual analytical examinations of samples, the work pertinent to field laboratory operation involves contacts with municipal officials and with industrial managements for factual information, collection of samples, measurements of sewage and industrial wastes flows, stream sampling, and collection of data pertinent to hydrological studies of receiving streams. The field work directly essential to the operation of the unit during the nine months of 1949 required approximately 750 man-days. Samples analyzed numbered as follows: Stream, 581; municipal sewage, 244; and industrial wastes, 208. The total number of analytical determinations on these samples closely approached 6,000. Emphasis thus far has been placed on chemi-

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FIGURE 1.—Ohio's modern mobile stream pollution survey laboratory unit.

cal analyses. Cognizance is had that bacteriological and biological examinations are most valuable in the interpretation and control of stream sanitation. However, an initial evaluation of the problems, conserving time and personnel, has had priority, hence the decision for limiting efforts largely to chemical and biochemical examinations.

Miami River Survey

General

The major role of the mobile laboratory during the past year was an overall pollution survey of the Miami River and its tributaries. Consequently, a brief review of this survey and a limited discussion of the highlights of this

FIGURE 2.—Station wagon used as tow car serves also for collection of samples and as a crew carrier.

study appear warranted. Briefly, the field work involved procuring factual information with respect to municipal activities and with respect to industrial processes; evaluating, by flow measurements and analyses, sewages and industrial wastes discharged to the river and its tributaries; and observing, by river sampling and analyses, the effects of pollution loads on the streams under the current hydrological conditions. The second phase of the work has been the correlation of data, including stream sanitation analysis, for determining recommended allowable pollution loads for sections of river and for river tributaries. For this discussion, reference, in general, will be made to the study only as it has applied to the main stem of the river from Tipp City to its confluence with the Ohio River.

Pollution Loads

Distributed over the Miami River drainage area in Ohio, a total of 3,948 sq. mi., the organic pollution loads are pictorially represented in Figure 4. The network of sampling points for observing the effects of pollution on the river and its tributaries is shown in Figure 5. Reference to Figure 4 definitely shows that the section of the Miami River from Dayton to its confluence with the Ohio contains the major concentration of organic pollution.

Table I sets forth evaluations of significant organic pollution from Tipp City downstream. Loads expressed as population equivalents (based on 5-day B.O.D.) at focal points are listed under headings "untreated" and "discharged." The load attributed to paper mills, an important industrial activity, represents 47 per cent of the total organic pollution.

FIGURE 3.—Trailer unit contains equipment and supplies for all usually required chemical, bacteriological, and biological examinations.

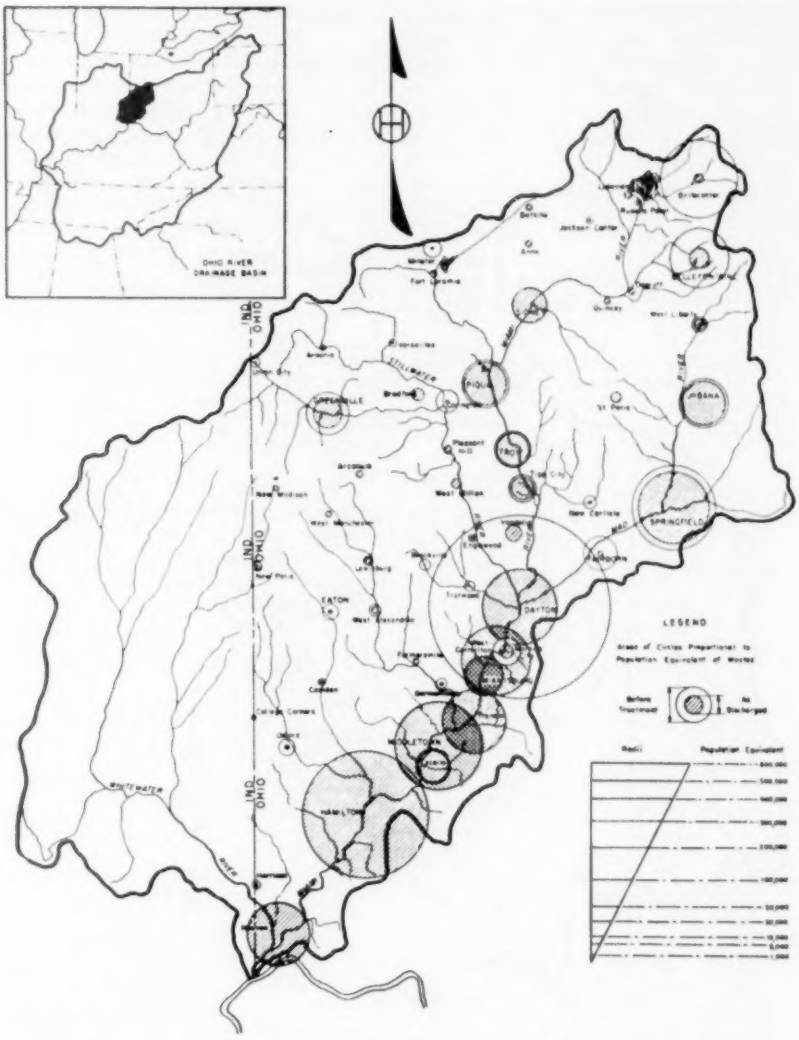

FIGURE 4.—Sources of significant pollution in Miami River Basin, 1949.

Full cognizance was taken of inorganic wastes influences with the evaluation of those characteristics that can have deleterious effects on the surface waters. For the most part, these required special consideration in more limited reaches of the river. Of the significant inorganic wastes, there were acid iron wastes and wastes resulting from the electroplating of metals.

Phenolic wastes from one by-product coke plant and from one oil refinery have significance, as do oils and allied substances characteristic of the latter industry. Phenols, particularly, have required special consideration because

FIGURE 5.—Location of sampling points in 1949 survey of Miami River Basin.

of tastes and odors imparted to waters used for public water supplies. The Miami River below these influences is not used in this manner, but the Ohio River immediately downstream from the confluence (Aurora, Ind.) is so used.

Hydrological Aspects

Stream flows in the Miami River and its tributaries were above normal during the 1949 summer and fall months. Inability to observe pollution effects or the response of the river to pollution loads under drought condi-

tions has made the over-all river analysis much more difficult. However, armed with the field data as outlined above, thorough study of stream flow records for the determination of the frequency of severe drought flows and of less severe drought flows has been made. It is not reasonable nor economically feasible to fix pollution abatement requirements on the lowest flow of record or on a condition the probable occurrence of which will be once in, say, 25 years. Therefore, from the stream flows of record "critical flows" have been selected, which in the case of the Miami River are seven consecutive day averages that will probably occur not oftener than once in five years. Cognizance must be had that the activities of Mother Nature from year to year, month to month, or even day to day, do not always follow similar patterns; consequently, what has occurred over past years must be used scientifically as a guide to future probabilities.

TABLE I.—Sources of Significant Pollution of Miami River from Tipp City to Mouth, Including Industrial Waste Expressed as Sewered Population Equivalent (B.O.D.)

Municipality	Miles Above Mouth of River	Est. Pop. Connected to Sewers	Sewage Treatment	Sewered Pop. Equiv.[1]	
				Untreated	Discharged
(*a*) By Domestic Sewage and Industrial Waste					
Tipp City	104.2	3,167	Secondary	10,790	7,990
Vandalia	97.4	4,000	Primary	4,000	3,920
Dayton	84.2	300,000[2]	Secondary	513,550[2]	83,550[2]
Moraine City	—	11,650[3]	Secondary	11,650[3]	2,720[3]
West Carrollton	71.5	2,393	None	73,350	73,350
Miamisburg	69.0	6,500	None	22,010	22,010
Franklin	60.9	5,700	None[4]	64,760	64,760[4]
Middletown	53.6	41,500	None	116,700	116,700
Excello	46.5	2,000	Primary	16,620[5]	15,780[5]
Hamilton	35.3	66,000	None	245,000	245,000
Hooven	8.0	None[6]	None	60,700[6]	60,700[6]
Total	—	442,910	—	1,139,130	696,480
(*b*) By Paper Industries					
Tipp City	—	—	—	7,730	7,730
Dayton	—	—	—	22,000	22,000
West Carrollton	—	—	—	64,690	64,690
Miamisburg	—	—	—	8,810	8,810
Franklin	—	—	—	55,460	55,460
Middletown	—	—	—	57,310	57,310
Excello	—	—	—	15,390[5]	15,390[5]
Hamilton	—	—	—	156,600	156,600
Total	—	—	—	387,990	387,990
(*c*) By Industries other than Paper Mills					
Total	—	—	—	308,230	128,000[7]

[1] By 5-day B.O.D.
[2] Includes Oakwood and Frigidaire.
[3] Includes Carrmonte sewer.
[4] Sewage treatment plant not used.
[5] Includes Sall Mountain Paper Co.
[6] All industrial waste.
[7] Estimated.

Frequency curves were developed (Figure 6) to show per cent of years when specified minimum flows were greater than those shown. Minimum monthly averages, minimum 14-day averages, minimum 7-day averages, and minimum daily flows for the period of record at Hamilton, for instance, have occurred at frequencies as read directly from the chart. It is indicated that for 80 per cent of the years the minimum average monthly, 14-day, 7-day and daily flows have been 420, 380, 350, and 290 c.f.s., respectively, or greater. Conversely, it is indicated that for 20 per cent of the years (one year in five) the respective flows had the above respective values or lesser values. Such a chart was developed for flows of record at each gaging station. These furnished considerable guidance in the selection of "critical flows."

Table II sets forth, for the river at Hamilton, periods of continuous flows of 7 days or more when the flows were equal to or less than specified values in the lower range of discharges. Observance of these data indicate that flows less than 350 c.f.s. have occurred at relatively infrequent intervals, about in the frequency of one year in six, for the 25.3-yr. period of record. Similar tables were developed for flows of record at each river gaging station.

The minimum 7-day average flows were selected as "critical" for the reason that a condition more or less constant for such interval results in serious pollutional effects.

From the analyses of the above instruments, considered particularly pertinent, as well as of other hydrological data, it was concluded that the low flows which could be expected to occur about one year in five to seven years, or 20 per cent of the time, are "critical" and can reasonably be selected as those on which to base reductions of organic pollution loads. Table III, therefore, presents the critical flows at four major gaging stations on the main stream. These values were plotted, from which straight line interpolation gave values

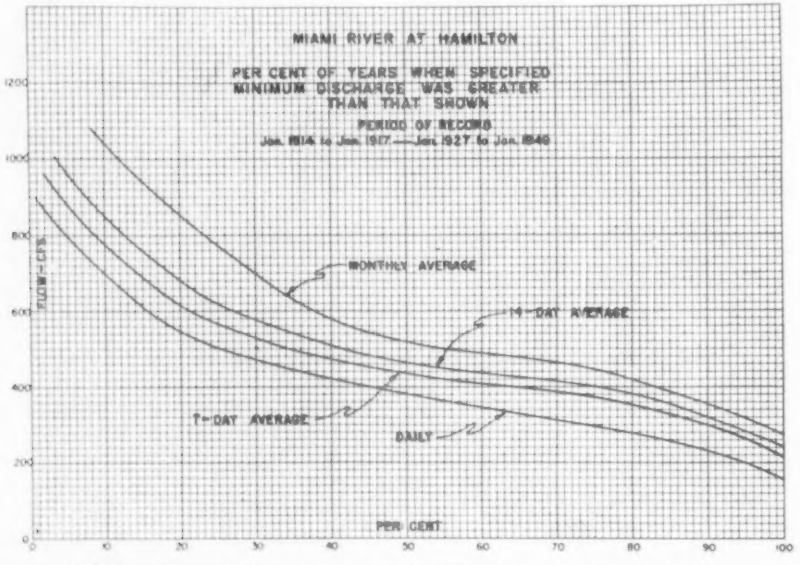

FIGURE 6.—Flow frequency curves for Miami River at Hamilton, Ohio.

TABLE II.—Miami River at Hamilton; Periods of Continuous Flow of 7 Days or More When Flow was Equal to or Less Than That Shown; Period of Record, 25.3 Years

Year	450 c.f.s.		400 c.f.s.		350 c.f.s.		300 c.f.s.		250 c.f.s.	
	Dates	Days	Dates	Days	Dates	Days	Dates	Days	Dates	Days
1914	7–24 to 8–7	15	7–24 to 8–7	15						
	8–16 to 8–24	9	8–16 to 8–24	9						
	9–12 to 9–22	11	9–15 to 9–22	8						
	9–28 to 10–12	16								
1928	10–4 to 10–10	7								
1930	7–20 to 8–5	17								
1932	8–20 to 8–27	8								
	9–5 to 9–20	16	9–9 to 9–19	11						
1934	6–11 to 6–21	11	6–12 to 6–19	7						
	7–11 to 7–26	16	7–13 to 7–26	14	7–15 to 7–26	12	7–17 to 7–26	10		
	7–30 to 8–9	11	7–30 to 8–9	11	7–30 to 8–9	11	7–31 to 8–9	10		
	8–26 to 9–28	34	8–27 to 9–28	33	9–20 to 9–28	9				
	10–6 to 12–31	87	10–7 to 12–26	81	10–12 to 12–19	69	10–27 to 11–5	10		
							11–10 to 11–20	11		
1935	1–1 to 1–18	18	1–1 to 1–17	17						
	10–3 to 10–10	8								
1936	7–1 to 8–28	59	7–7 to 7–24	18	7–14 to 7–24	11				
			7–26 to 8–28	34	7–28 to 8–19	23				
	9–5 to 9–23	19	9–6 to 9–16	11						
1940	9–13 to 9–25	13								
	9–28 to 10–26	29	9–28 to 10–24	27						
1941	8–6 to 8–18	13								
	8–25 to 9–2	9								
	9–8 to 10–4	27	9–13 to 10–4	22	9–14 to 10–4	21	9–20 to 10–2	13	9–25 to 10–2	8
1944	8–6 to 8–12	7								
	9–9 to 9–26	18								
	10–2 to 11–14	34	10–14 to 11–8	26	10–26 to 11–1	7				
	11–30 to 12–13	14								
	12–16 to 12–24	9								
1945	1–19 to 2–8	21	1–28 to 2–7	11						

for application at intermediate points of concentrated pollution (Figure 7).

Water Quality Objectives

Having established "critical" or, perhaps better, "design" river flows, it was necessary to establish for sections of the river, water quality objectives consistent with water usage and with potential usage. From the standpoint of deoxygenating wastes it was considered reasonable to establish a minimum dissolved oxygen content of 4 p.p.m. for the river in the general Dayton-Middletown-Hamilton area. This dissolved oxygen content applies to summer conditions or, more specifically, to a water temperature of 25° C. This value, then, was used to arrive at the capacity of the stream to receive wastes normally using the oxygen in water in the processes of decomposition and stabilization.

Other criteria were also selected that control disposal of wastes of inorganic composition and of particularly significant characteristics. The water quality objectives established for this section of the river are set forth in Table IV. It should be recognized, however, that these recommended tolerable limits will vary from location to location, depending on the use that may reasonably be expected of the surface water.

TABLE III.—Critical Miami River Flows at Existing U.S.G.S. Gaging Stations

Location	Drainage Area (sq. mi.)	Flow (c.f.s.)
Sidney	545	30
Taylorsville	1,155	60
Dayton	2,513	225
Hamilton	3,639	350

Analysis of Pollution Reduction Recommended

Were it possible always to observe conditions at times of critical low flows, the problem of determining the necessary reduction of pollution would be much less difficult. From the standpoint of the regulatory agency, a quick method of the correlation of offshore pollution, of observed pollution effects at the time of survey, and of expected effects at critical low flows, is certainly most desirable. However, an evaluation of the factors influencing the self-purification capacity of a stream cannot be neglected in a reasonable approach to determining the requirements of pollution reduction consistent with water usage. Consequently, in this initial extensive river pollution study, considerable time has been devoted to exploring the methods of approach so as to expedite the application of information that can be obtained readily by field analyses and thus increase the efficiency of the mobile unit.

In the study for organic pollution reduction, application has been made of the Streeter-Phelps method for determining the natural self-purification capacity of a stream based on the oxygen sag curve. Also, use was made of an abbreviation of the above method developed by LeBosquet. Within the limits of observed river data, reasonable checks were obtained. The methods are considered valid and furnished the framework upon which a practical evaluation of stream conditions could be built. Considering the variable factors generally attributed to biological and hydrological changes, all analyses have been made with an aim of producing results that can be justified practically.

The study, conducted as briefly outlined, has developed that water quality objectives in the lower reaches of the Miami River probably can be attained if organic pollution loads (based on 5-day B.O.D.) actually measured in the field during the 1949 survey are reduced as follows: At Tipp City, 80 to 85 per cent; at Dayton, 85 to 90 per cent, and at the focal points below Dayton, West Carrollton through Hamilton, 70 to 75 per cent.

TABLE IV.—Recommended Water Quality Objectives for Critical Low Flows of Miami River from Dayton to Mouth

Number	Component	Tolerable Limits
1	Dissolved oxygen	Not less than 4 p.p.m.
2	pH	Between 6.3 and 9.0
3	Chlorides (as Cl)	Not over 250 p.p.m.
4	Phenols	Substantially complete removal (Tentatively not over 25 p.p.b. to 30 p.p.b., especially during critical flow periods in cold weather)
5	Iron	Not over 5 p.p.m.
6	Manganese	Not over 5 p.p.m.
7	Zinc (as Zn)	Not over 15 p.p.m.
8	Nitrates (as N)	Not over 10 p.p.m.
9	Cyanide (as Cn)	Not over 0.15 p.p.m.
10	Lead (as Pb)	Not over 0.35 p.p.m.
11	Copper (as Cu)	Not over 0.40 p.p.m.
12	Chromium (hexavalent as Cr)	Not over 2 p.p.m.
13	Oils	Substantially complete removal
14	Free acid	None
15	Color and odor	To be nonoffensive
16	Other toxic wastes, deleterious substances, and high-temperature liquids	None alone or in combination with other substances in sufficient amounts to impair water usage

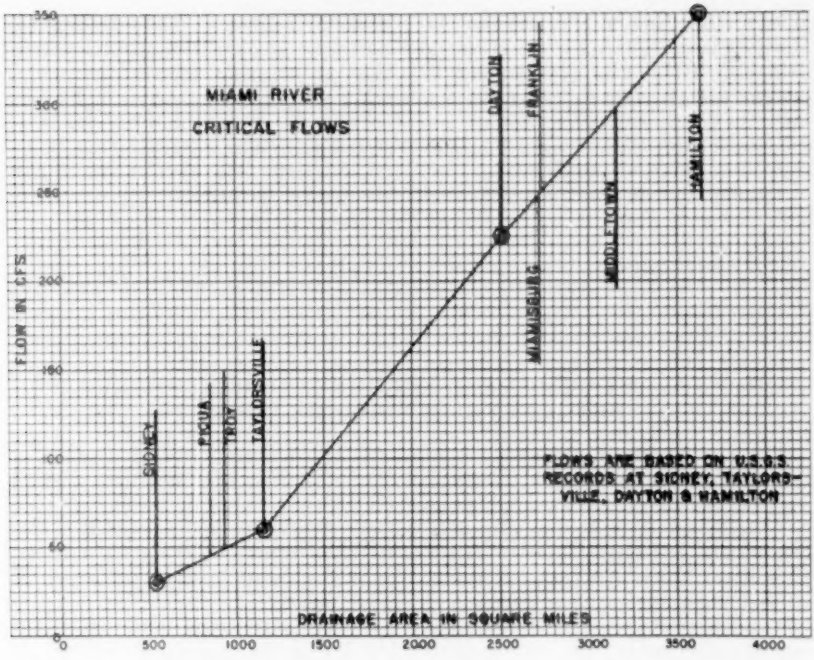

FIGURE 7.—Method of determining critical flow at various points on Miami River between gaging stations.

This confirms presurvey recommendations of this department based on routine investigations and general observations. The degree of sewage and organic waste reduction had been tentatively fixed at 65 per cent below Dayton. The inclination is to accept this as the initial goal pending an opportunity for check stream surveys under conditions more nearly approaching the "critical" flows selected.

Tolerable loads for each agency, therefore, can be readily prescribed. These in turn will fix the degrees of treatment or degrees of wastes elimination necessary to maintain within reasonable limits satisfactory stream water characteristics.

Practical consideration of the inorganic wastes and wastes of special characteristics in relation to dilution furnished at periods of critical flow indicate that the water quality objectives can be attained by reasonable methods of wastes reduction and disposal.

Summary

The mobile laboratory unit has been a most valuable asset in the initial efforts of the Ohio Department of Health to comprehensively evaluate water pollution. Each river basin requires an independent study. "On the spot" analyses lends to accuracy of results and to savings in time and personnel. The unit serving as field headquarters makes more readily possible the observations of stream conditions at times and at frequencies when analytical data correlated with critical hydrological conditions can be most useful in the interpretation of the capacity of the stream to receive and absorb pollution loads. This is important, on the premise that the streams should be

used for the disposal of sewage and industrial waste effluents; but to an extent only that water qualities can be maintained for water uses consistent with the public health and welfare and consistent with the potential economic and social needs of communities.

During the first year's operation, experience gained by Ohio Health Department personnel in the interpretation of variable factors influencing self-purification of streams and in the correlation of data most pertinent to stream sanitation analyses should make possible more efficient use of the mobile laboratory facilities.

OHIO VALLEY COMPACT QUESTIONS TO BE REVIEWED BY UNITED STATES SUPREME COURT

The United States Supreme Court has consented to review the recent action of the Supreme Court of Appeals of West Virginia in holding that ratification and enactment into law of the Ohio River Valley Sanitation Compact by that State was unconstitutional and that appropriation of funds by the legislature to cover that state's share of the expense of operating the Ohio River Commission was improper. The main question to be decided deals with whether the power of a state of the Union to enter into compacts with other states to which consent of Congress has been given pursuant to Article I of the Constitution can be limited or restricted by provisions of the state's own constitution. The action of the West Virginia court upheld the state auditor in his refusal to honor a requisition for payment of West Virginia's share of operating funds for the Commission.

Other questions on which the United States Supreme Court has been asked to rule include:

1. If the power of a state to enter into compact with other states can be restricted by the provisions of its own constitution, does the Constitution of the State of West Virginia restrict such power?

2. If the Constitution of the State of West Virginia can and does restrict that State's power to enter into compacts with other states, does the Ohio River Compact subject West Virginia to any obligation in violation of its constitution?

3. Has ratification and enactment into law of the Ohio River Compact by the West Virginia legislature resulted in an unconstitutional delegation of police power or legislature authority?

The case has attracted nation-wide interest because the issues affect the future of many other interstate compacts now operating in different parts of the country. Review of the case by the Supreme Court of the United States was sought by the State of West Virginia, represented by its commissioners in the Ohio River Commission, and by representatives of the West Virginia State Water Commission. Other briefs filed in support of the petition for a review of the case included one by the attorneys-general of Ohio, Indiana, Kentucky, Illinois, New York, and Pennsylvania, these being other states party to the Compact; one for the United States, by the Acting Solicitor General; and one by the general counsel for the Interstate Commission on the Potomac River Basin.

OPERATION OF A FIELD LABORATORY UNIT IN WATER POLLUTION SURVEYS*

By Wallace W. Sanderson

Chemist, Division of Laboratories and Research, State Department of Health, Albany, N. Y.

The New York State Water Pollution Control Board, established in accordance with the Public Health Law, is required in its classification of waters to consider "the extent of present defilement or fouling of said waters which has already occurred or resulted from past discharges therein (1)." Thus, studies of the sanitary quality of the water are necessary at the time of the survey.

These can be made only by laboratory examinations. No other method is sensitive enough to measure the minute quantities of polluting material that may be deleterious to man or aquatic life. No other means will disclose the density or extent of bacterial contamination from sewage. An estimate of the concentrations of dissolved substances cannot be made by visual observation. The biologic changes and the rates at which they occur can only be measured by laboratory examination. The tests to be made, and the limitations and accuracy of each, must be clearly understood before the results can be effectively or intelligently used in forming an opinion of the sanitary quality of any particular water.

In addition, enough data must be collected so that an estimate can be made of the quality of the water that will prevail at other times when conditions of flow and temperature are different. Admittedly, the projection of data collected at one time to what might occur at another is difficult and subject to question, but if the 70,000 miles of streams and more than 3,000,000 acres of surface water in New York State are to be covered within a foreseeable time, surveys cannot be confined to periods of high temperatures and uniform flows. Even with the field units operating continuously for 9 months of every year, it will require at least 10 years to examine the waters of the State. Because of low temperatures, ice, snow, and high stream flows, it is not practicable to operate a field laboratory from the middle of December to the middle of March; in some sections of the State work cannot be begun until the end of May.

Industrial Water Quality Also Desired

Samples of each waste discharged to the waters must be examined to determine its various constituents and their concentration in order to estimate their probable effect on the receiving water. The Commissioner of the Department of Commerce has requested in some instances that additional data be obtained during surveys regarding the suitability of the water for industrial uses. The concentrations of silica, iron, calcium, magnesium, and sulfates, normally of little importance in determining the sanitary quality of water, may be factors that govern the possible use of a water for industrial purposes. Many of the limiting concentrations of constituents in the receiving waters are established by the tolerance of fish. The Conservation Department makes all biologic examinations, but information regarding

* Presented at 1950 Spring Meeting, New York Sewage and Industrial Wastes Association; Jamestown, N. Y.; June 12–13, 1950.

FIGURE 1.—Field tests on samples, showing kit for chemical tests, sampling equipment, and ice chest set up in jeep.

the concentrations of materials deleterious to fish is determined by chemical examinations by this Division.

To provide facilities for such a volume and variety of laboratory work, space, personnel, and equipment were made available in the Division of Laboratories and Research of the New York State Department of Health at Albany. The examination of samples of wastes, sewage, and water for those components that do not change during shipment is not made routinely in the field, but is undertaken in the central laboratory. Methods for treating many industrial wastes are not now known. Studies of such wastes must therefore be made and methods of treatment investigated. Studies of laboratory procedures for their adaptation to the examination of wastes containing miscellaneous constituents is a major problem in the Sanitary and Analytical Chemistry Laboratory of the Division. The procedures to be used for determining compliance with the standards for the various classes of water must be defined. Many of the technics must be varied for each waste because of the presence of interfering substances. Thus, a method may be standard for only one particular waste.

Mobile Laboratory Unit

Most of the routine laboratory tests for determining the sanitary quality of streams must be performed in the field immediately after the sample is collected, because of changes by biologic and chemical action. Similarly, some of the tests of sewage and wastes must be made at the time of collection. To provide facilities for this, a laboratory that can be moved to all parts of the State is required. Hence, a mobile laboratory was borrowed from the U. S. Public Health Service Environmental Health Center at Cincinnati, Ohio, and equipped for stream pollution investigations.

A Willys-Overland jeep station wagon with 4-wheel drive and oversized tractor-tread tires was purchased for the transportation of equipment

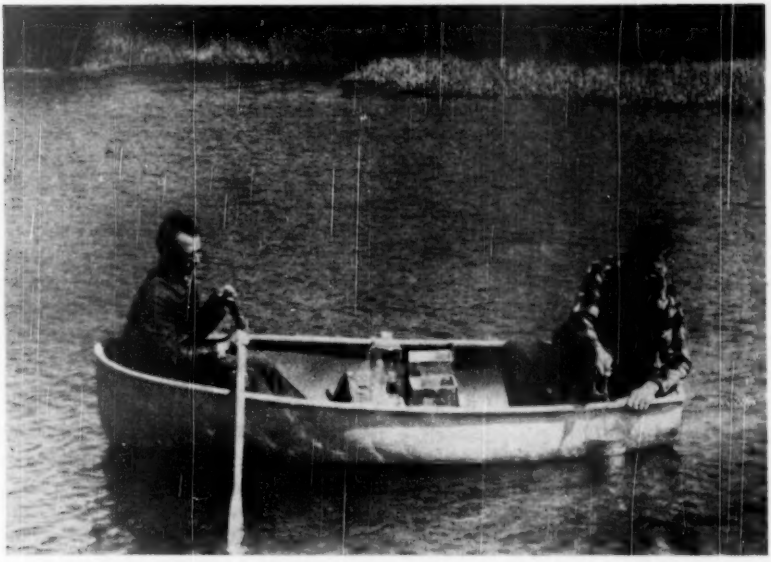

FIGURE 2.—Collection of sample in pond from aluminum boat.

required for chemical tests, flow measurements, and for the collection of samples from the selected points on the watershed (see Figure 1). A winch driven by a power take-off from the motor lowers and raises sampling equipment from high bridges.

An 8-ft. aluminum boat, weighing only 65 lb. with outboard motor, was provided for sample collection in small streams and ponds; it is transported on a trailer attached to the jeep (see Figure 2). In large rivers and lakes a more stable boat is hired, as the aluminum boat is not satisfactory in rough water.

The field unit began operation in September, 1949, and valuable experience and knowledge of the type of laboratory most adaptable to the purpose was obtained. The use being made of this laboratory is not the purpose for which it was designed, and the following comments are not to be taken as criticism of the unit; they are recorded only for those who may have a similar problem. It is constructed on a house trailer chassis and drawn by a 1.5-ton truck by a pintle hook attachment. The tow truck is too heavy to drive to sampling points not on a paved highway and, therefore, cannot be used for sample collection. The laboratory is moved only three or four times a year, so that the truck is not an essential investment. In the examinations an analytical balance is used, but the stationary supports of the unit are not sufficient to prevent movement of the trailer, and the balance requires repeated releveling. The power requirements necessitate a single-phase 110-v. line capable of supplying 65 amp. Transformers must be installed by the local power authorities to meet these requirements, a costly arrangement which is not always convenient. The unit is exceedingly hot in the summer and the floor is very cold in the late fall. Days did occur when a temperature of 65° F. was maintained at bench top level, but samples froze when placed on the floor. Two men work in the unit most of the time and occa-

sionally three are present, but the laboratory is not large enough for this. With a staff of three, some of the equipment, especially the 20° incubator, is not of sufficient capacity for the number of samples under examination.

New Unit in Construction

An attempt to correct these difficulties was made in the design of a mobile laboratory now being constructed for the Division of Laboratories and Research. The advice of the Environmental Health Center was again solicited and advantage was taken of their experience. They had designed a laboratory on a flat-bottom trailer to be drawn by a standard tractor with a fifth wheel (2). This design, with very few modifications, was adopted. The standard fifth-wheel hitch makes it unnecessary to purchase a tractor, as one can be hired in nearly every city in the State. The unit is much heavier than the one now in use and steadier for laboratory equipment. It is 28 ft. long and 7 ft. wide on the inside. The power supply is 220 v., which can be obtained conveniently. Both the roof and the floor have insulation.

Unit Personnel

The water pollution studies are made under the administrative direction of the Executive Secretary of the Water Pollution Control Board, utilizing the facilities of the Board member Departments and such other agencies as are available. The Secretary determines which streams are to be studied and when the studies are to be made.

The field party consists of one senior and one assistant sanitary engineer from the Bureau of Environmental Sanitation, one senior and two junior sanitary chemists from the Division of Laboratories and Research, and two aquatic biologists from the Conservation Department. While in the field this group is under the direct supervision of the senior engineer, although direction and responsibility for the technical work of the various staff members rest with the division from which they are assigned. It is the function of the engineers to establish sampling points, and to make industrial wastes surveys and flow measurements. The chemists collect the samples and make the necessary laboratory determinations. The biologists perform the biologic surveys and toxicity studies. Although the individuals in the party have different functions, they all work under the supervision of the sanitary engineer for a common purpose, and cooperation is very close.

Field and Laboratory Determinations

The mobile laboratory is hauled to a central location on the watershed being investigated. It is practical to study only the area within a 25-mi. radius, as sections farther away require too much travel time in the transportation of samples. The routine tests made on stream samples are as follows: color, odor, turbidity, suspended matter, temperature ° C., pH value, carbon dioxide, dissolved oxygen, 5-day biochemical oxygen demand (B.O.D), nitrates, chlorides, alkalinity, most probable number of coliform bacteria, and the standard plate count. In general, the procedures described in "Standard Methods" (3) are followed.

In most studies, two or three samples from each sampling point are collected at weekly or biweekly intervals, depending on the area covered. Sampling stations are selected at significant points above and below sources of pollution. When studying a main stream or lake, at least one station is located on each tributary just above the confluence. On large streams more than one sampling point at a station may be used to give a cross-section of the stream and thus compensate for unequal distribution of its constituents. If the stream is more than 20 ft. deep, samples may be taken at various depths. Similarly, in lakes, a gridiron

pattern of stations is set up and samples at several depths may be required.

One chemist collects the samples, which consist of a portion for dissolved oxygen, a duplicate portion for B.O.D., and 0.5 gal. for return to the mobile laboratory. The sampling equipment used prevents aeration of samples for dissolved oxygen and biochemical oxygen demand examinations. At the same time, a separate sample for bacteriologic examination is collected in a sterile bottle, which is iced and maintained at 40° F. during transportation.

At the time of collection, observations of the appearance of the streams are made: color, odor, turbidity, and suspended matter are noted as they would appear to a layman. A descriptive term is used preceded by a numeral indicative of intensity; for example, "3 grayish-green" means the stream from the bank appeared distinctly grayish-green in color, regardless of whether this was due to the water, the bottom, or reflection from the sky. Notation is also made of the type of bottom and any deposits or débris.

The temperature of the water is measured to the nearest degree C. Colorimetric determination of the pH value is made with a comparator kit. Carbon dioxide is titrated and the fixation of dissolved oxygen is performed using the Alsterberg modification of the Winkler method, the procedure being carried up to the liberation of iodine. Titration of the iodine is generally done after three or four samples have been collected, which is within a period of 2 hr. In some samples, where interfering substances are present, different procedures for dissolved oxygen must be used. It is the responsibility of the chemist to decide when and what procedure shall be employed.

The collection of samples is started at 7 A.M. and all samples are returned to the mobile laboratory by 1 P.M. Thus, the maximum elapsed time between collection and receipt at the laboratory is 6 hr. and the majority of the samples are received much sooner.

The half-gallon portion of sample is returned to the mobile laboratory for routine examination. The color of the sample is determined by comparison with color standards after clarification by sedimentation. This yields a value which shows changes that occur in a stream caused by its tributaries, discharge of wastes, or biologic activity. The turbidity is measured by comparison with standards in bottles; added wastes affect the results, and the effect of tributary streams, particularly in lakes, can often be traced. Odor is determined by sniffing the mouth of the sample bottle after it has been warmed to room temperature. This is one of the most sensitive tests that can be used, as the nose detects odors caused by concentrations of substances far below the sensitivity of most analytical procedures. Nitrates are measured by the phenoldisulfonic acid method and permanent standards prepared by the Division of Laboratories and Research (4). Chlorides are determined by titration with silver nitrate. The results of these two tests are very useful in measuring pollution; the first gives an estimate of the total nitrogenous material added, while chlorides are unchanged in a stream except by dilution. Alkalinity is measured by titration with standard acid solution. The results disclose the addition of alkaline or acid wastes and are of particular value in determining the toxic effect of many substances on fish.

Routinely, the duplicate portion for the dissolved oxygen test is incubated for five days to determine the B.O.D. If dilutions must be made, standard phosphate buffered dilution water is used. The results of this test, together with the dissolved oxygen values, disclose the concentration of putrefactive organic matter and the rate of purification in the stream.

An estimate of the coliform group of bacteria is obtained by inoculation of three tubes of lactose broth with each of several decimal dilutions of the sample. Confirmation of the presence of coliform microorganisms is made in brilliant-green bile broth. These microorganisms are used as indicators of sewage pollution and thus of a possible menace to health. Agar plates of decimal dilution portions of samples are made to determine the plate count at 36° C. after 24-hr. incubation. This examination gives an estimate of the total number of microorganisms present and is markedly affected by the wastes added to the water and the biologic activity occurring in the stream. The purpose of this series of tests is to detect and measure the presence of pollution and the changes that occur after pollution is added. Not many of the tests would detect all types of pollution and, conversely, very few types of pollution would not be detected by some of the tests.

Flow Measurements and Wastes Samples

The engineer, before and during the laboratory study of the watershed, surveys the sources of pollution reaching the streams. Subsequently, a visit is made by both the engineer and the chemist to the industry or municipality contributing pollution to arrange for the measurement of flow and the collection of samples of wastes. Flows are generally measured at weirs and with a liquid-level recorder. A water meter adaptable to various size pipes is also available.

The method of sampling varies widely in different industries and even different plants of the same industry. When a continuous flow of wastes occurs it is the practice to collect portions at hourly intervals for 24 hr. and mix them in proportion to the flow at the time of collection. Sometimes, sampling is repeated on two or three days. In other industries where batch discharges occur, a few catch samples from individual batches is satisfactory.

The chemist must learn during the survey what constituents are present in the wastes for which analyses should be made. It is also his duty to see that the samples are properly collected. At the time of each waste sampling an additional study of the receiving stream is made above and below the discharge point to show the effect on the water. The routine stream examination is changed to include determinations of the various substances that may be in a particular waste and, thus, their concentration after dilution in the stream.

Many of these determinations, such as the distribution of solids between the suspended and the dissolved state, cyanide in its various forms, B.O.D., and pH value, must be made in the mobile laboratory soon after samples are collected. Other substances such as the metals, grease, phenol, and organic nitrogen can be preserved in the sample which is shipped to the Albany laboratory, where more adequate facilities are available. It obviously would be impossible to equip a mobile laboratory for all the examinations that might be required for all industrial wastes.

Many determinations in sanitary chemistry are not specific for one substance and many are not accurate at very low concentrations. For these reasons, the standards for the various classes of waters cannot be specific and can only define a polluting substance in terms of the determination of that substance by a particular laboratory method. Each report on a watershed survey, therefore, includes a description of the procedures used for the laboratory examinations in that investigation.

Unit Productivity

During the 1949 studies of the Rondout watershed, the laboratory unit collected and examined an average of six routine stream samples per

working day. The working day theoretically consists of 7½ hr., Monday to Friday inclusive, with sampling continued regardless of the weather. Actually, the chemists work seven days per week to carry on the bacteriologic and biologic tests, although one or two generally can be spared each weekend. The collection and examination of industrial wastes samples averaged a little more than one sample per working day, but this varied with the terrain covered and the distances to sampling stations. In the present study of Chautauqua Lake, an average of seven samples per working day has been examined, the increase possibly due to the experience gained last year and to the greater ease of sample collection in the lake.

Summary

This is a description of the present laboratory operation. In general, it consists of a central laboratory equipped for research and special examinations; a mobile laboratory equipped for routine field investigations; a jeep and a rowboat for sample collection and on-the-spot testing. Many changes may be made as more experience is acquired and more varied conditions are met. In any case, the results will be of value only if they yield information that will aid in the control of pollution of the State's lakes, streams, and rivers.

References

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2. "Specification for Tractor and 28-ft. Semi-Trailer Laboratory." Environmental-Health Center, U.S.P.H.S., Cincinnati, Ohio. Mimeo. 18 pp. (Dec., 1948).
3. "Standard Methods for the Examination of Water and Sewage." 9th Ed. Amer. Pub. Health Assoc. (1946).
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CHRISTMAS GIFT SUGGESTION

Is there a professional friend or associate for whom it is always difficult to select a suitable nonpersonal Christmas gift? Here's one suggestion that will answer the problem for you—give him a copy of the 20-Year Index to *Sewage Works Journal*. Not only will the volume make an excellent present for this Christmas, but also you'll be giving him a gift of valuable time saved whenever he needs to look up the answer to a technical sanitation problem.

The 20-Year Index, at $4.50 per copy, is available from The Garrard Press, Champaign, Ill.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

OPERATION AND MAINTENANCE INVENTORIES

The approach of year's end, which means inventory time for so many plants, affords an excellent opportunity for taking stock of the operating and maintenance supplies and equipment on hand and planning a sensible program of building up these inventories to meet foreseeable normal and emergency demands. Not all eventualities can be foreseen; but for those that can, it is inexcusable to be caught unprepared because of some minor item overlooked in advance planning.

The possibility of the present world situation developing into another major conflict must be faced realistically. Each plant staff must decide for itself what the impact on its situation may be by reason of probable government controls on equipment, supplies, and materials, defense requirements, priorities, etc., in the light of its own peculiar circumstances as reasonably predictable. In this, past experience and plant records will play a major role; but calm reflection and good judgment will be just as important. To go "hog wild" in stocking up heavily on every item even remotely connected with plant requirements is certainly not the answer to the problem.

If stringent governmental controls do materialize, indications are that they no doubt will be similar in most respects to those in effect during the last war. But sewage and industrial waste treatment plants can reasonably expect to enjoy pretty high priority ratings in acquiring needed equipment and supplies. In addition to being utility-type operations, they are directly and vitally concerned with the public health, even more necessary in a stepped-up war production effort with its attendant reduction in disease resistance.

Recent announcement of "voluntary priority controls" in the metals industries seems to be only an interim step to allow preparation of full controls, not only on materials, but also on manpower, wages, prices, and a multitude of other factors affecting supply and demand of essential supplies and services.

To build up vital maintenance and operation inventories in anticipation of short supply eventualities is only good business. On the other hand, to impound too much of one's working capital or operation budget in the frozen assets of excess inventory only reduces the plant's potential for meeting additional demands or changing requirements.

Inventory build-up, therefore, should be in accordance with a sensible, planned program based on realistic appraisal of present and future conditions as they may affect the particular plant involved. Such a program cannot be evolved by a wave of the hand or by snatching the answer out of thin air. It requires detailed consideration of each individual item of inventory, no matter how small. Time and effort are involved, but it will be time and effort well spent.

H. P. O.

OPERATING A DILAPIDATED SYSTEM *

By S. W. Hazlip

Supervising Chemist, Water Purification and Sewage Disposal Plants, Houma, La.

In the operation of a dilapidated sewerage system and treatment plant it is important to do all possible to operate so that the plant will not be a menace to health or a nuisance to the surrounding section. A dilapidated plant may be termed one that has been allowed to operate with very little attention, and one that has never given good results on the work it was designed for. Also, of course, it cannot be expected to do good work when heavily overloaded.

In the Houma sewerage system there are seven pumping stations in different sections of the town. Each delivers directly to the same main 21-in. line, which is about 1.5 mi. long. Three of the pumps deliver into the head of the line; four deliver into the lower section, about 0.5 mi. from the main (No. 1) pump station. From the point of delivery of each pump the flow is entirely by gravity to the No. 1 station. At times this results in a delay of the sewage getting to the plant. The No. 1 station is about 1.5 mi. from the disposal plant.

The disposal plant was erected about 1930. At present it is the same as when built, even though the load has more than doubled in the past five years. For two or three years it was given very little care and attention; thus, one might say it is a dilapidated system. This paper describes how the plant has been operated during the past three years in an attempt to overcome the several shortcomings.

Septic Raw Sewage

Delivery of the raw sewage to the treatment plant is delayed by the arrangement of the pumping plants as well as by the conditions of the lines, such as leaks, breaks, and sinking. Any of these may be the cause of delivering septic sewage to the plant, as well as cause of loss of sewage. There have been cases when the amount pumped was much more than that delivered to the plant. This same may be the cause of an extra amount during rains.

Delivery of septic sewage was giving considerable trouble, and a remedy was needed. At first a heavy dose of H.T.H. was tried; this was not very successful and the cost was high. Cloroben was then tried by adding it in the manholes just outside each pump station. This was very successful and is the method used at present. Heavy doses were tried, but there was soon trouble. Now light doses are added two or three times a week during the summer and early fall. There is not much trouble during the winter. Cloroben is used at all the pump stations except No. 1, where H.T.H. is always used.

Plant Problems

The No. 1 pump station delivers the sewage direct to the Imhoff tank. There is no grit chamber or provision made for sand, gravel, or other heavy solids. The result of this was that during the time the plant was allowed to operate with very little care or attention a heavy accumulation of sand, gravel, and other heavy material packed in the sludge compartment of the Imhoff tank. This required about two weeks to clean out thoroughly, and was the only remedy. Then the influent channel of the Imhoff tank was boarded up to form a small shallow basin that allowed all heavy solids to settle. This operates very successfully, but requires frequent cleaning.

In order to clean the Imhoff tank,

* Reprinted from "Proceedings, Twelfth Annual Louisiana Short Course for Water and Sewage Plant Superintendents and Operators, 1949." *Eng. Exp. Station Bull.*, Series No. 18, p. 53, Louisiana State University (1950).

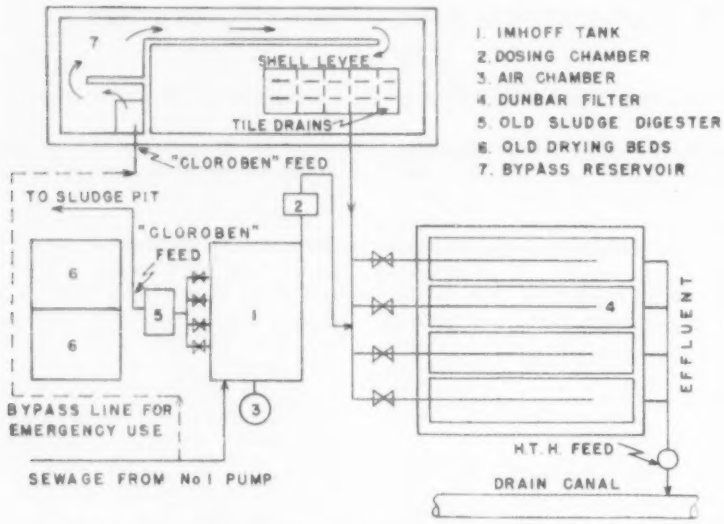

FIGURE 1.—Schematic layout of Houma sewage treatment plant.

special provision was made to by-pass the raw sewage to a large reservoir constructed in a wooded section next to the plant. The reservoir was made by ditching all around the plot and using this dirt as a levee. Also, a cross levee was made to direct the flow around the entire basin (see Figure 1). At the lower end inside the basin another levee was constructed of shell and rocks. From inside the latter, the effluent pipe of tile was laid. Thus, the sewage is well settled and then filtered through the shell and rock. It flows directly to the Dunbar filter drain, thence to the drainage canal.

At present the by-pass is used to handle excess sewage and excess rain water. At the time it is in operation a dose of Cloroben is used. It has been surprising that there have never been any odors, and very few flies, even when the pit is drying out.

Effects of Overloading

The overloading of the plant causes heavy carry-over of fine sediment to the filters, some of which even passes through the filters. However, most of it soon clogs the filters and thus reduces the capacity. The filter beds are worked often and an attempt is made to have a fresh one for use at all times. The sediment that passes through the filters has caused considerable trouble in the drainage canal. It has filled the canal to a depth of more than 1 ft. during the past three years, and is a soft jelly-like mass.

Foaming of scum has been very bad at times. Especially in the beginning of warm weather, this takes place mostly in the gas vent compartment of the Imhoff tank. At times the plant has had to be taken out of service to stop the foaming.

The gas chambers or vents were found to be too small and would soon fill so that the passage of gas was prevented. These were enlarged by adding a compartment on top of the old ones. Even these give trouble during foaming. At such times the cover is removed and the foam is beaten down as much as possible. Sometimes it has been necessary to draw the tanks down some and add lime.

Because of the heavy load the sludge does not have time to digest completely. The sludge digestion chamber and the drying beds are so small in size that they are no longer used. Instead, a reservoir similar to that of the by-pass arrangement was constructed for use as a sludge drying bed. The sludge flows by gravity through a pipe to this bed, which is about 150 ft. from the Imhoff tank. During the drawdown the sludge is dosed with Cloroben, which is allowed to flow into the line as sludge flows to the bed. There have been good results from this and very few complaints of odors or flies.

Due to the fact that the plant is considered a dilapidated one and its location is out of way, very few chemical tests are made. Usually, sight and smell are the indicators used in operation.

RECIRCULATION OF FINAL EFFLUENT IN A SMALL ACTIVATED SLUDGE PLANT *

By Leonard Hillis

Superintendent of Sewage Treatment, Caro State Hospital, Caro, Mich.

The Caro State Hospital plant is a small one treating only sanitary waste from an institution. It is understandable, therefore, that the sewage flow during the night and on Sundays would be very low, resulting in long detention periods (4 to 6 hr. or longer) in the primary unit. The waste from 300 to 400 patients, who are housed on the other side of the river, is pumped to the plant by float controlled pumps drawing from holding tanks, where it may remain as long as 4 to 6 hr. during low flow. Mixture of the unfresh raw sewage with the already stale contents of the primary tanks proves that two "poors" do not make a "good."

The results from this condition are somewhat alleviated during the colder months and do not have too much of a bearing on plant operation, but when the summer months arrive and the sewage has a constant temperature above 70° F. this long retention period brings about effects that are harmful to plant operation. Gas formation in the primary tank lifts large masses of settled raw sludge that must be broken up to settle again, or raked into the scum trough. The primary effluent is somewhat deteriorated and is not exactly good food for the activated sludge.

The results of this condition show up each Monday when the oncoming peak flows push the stale primary effluent to the aeration tanks, where the activated sludge has become lazy because of the lack of routine food. The peak flows, together with the stale primary contents, constitute what may be considered a shock load to the secondary treatment. These items alone may not warrant recirculation, however, as the 5-day B.O.D. of the final effluent was seldom more than 10 p.p.m. and usually around 5 p.p.m.

The scum trough and effluent weirs of the primary tank are covered by the scum room, which is part of the control building. This provides for easy and convenient cleaning during stormy and winter weather, but there are also disadvantages. The scum room has no roof ventilator or stack; two windows are the only means of ventilation. There were always unpleasant odors in the room, and during low flow in conjunction with hot and sultry weather conditions, the

* Reprinted from *Michigan Sewage Works Bulletin*, **6**, 2, 7 (May, 1950).

odors were very intense, not only in the scum room, but also outside. Weather stripping was used around the scum room door, thus odors escaping to the main part of the control building were held to a minimum.

No doubt the odors were due mostly to the formation of hydrogen sulfide. Light-colored paint used in the scum room did not hold its color very long. The white cornice on the outside of the building above the scum room windows turned color soon after the hot summer temperature began.

All these things led to the purchase of a portable pump that could be used for general purpose around the plant and to experiment with recirculation.

Effluent Recirculated

On May 16, 1949, the operator began recirculating during low flow periods. For two nights, chlorinated final effluent was pumped at a rate that reduced the primary retention period to a little more than 2 hr. The scum room odors were practically eliminated, but the chlorine seemed to have a toxic effect on the activated sludge. This was tried again later in the summer with the same results. Except for the trials just mentioned, unchlorinated final effluent has been used with many favorable results.

Various rates of recirculation were tried, but the rate giving the primary unit a retention of a little more than 2 hr. was found to be best. The main reason seems to be that the high rate of flow during the day does not permit wasting of return sludge without part of it being carried over the primary weirs. Therefore, most of the wasting must be done at night when a flow can be maintained to allow for proper settling of the waste sludge.

The scum room odors have been practically unnoticeable as compared to when recirculation was not practiced. The cornice above the windows did not discolor until September, when recirculation was discontinued for four days. Even in this short period the cornice started to discolor and plant operation in general seemed to be degenerating. As a result, recirculation was again resumed and will be continued until the sewage temperature falls to 68° F.

Added Benefits

If for no other reason than odor control, recirculation is worthwhile—but the benefits do not stop there. While recirculating, the primary retention period is not only reduced, but fresh food that would otherwise become stale is being carried to the activated sludge. It stands to reason that diluted fresh food is much better than the more concentrated stale food that is had without recirculation.

After a period of low flow and recirculation, the contents of the primary tank are diluted, fresh, practically odorless, and in excellent condition to absorb the first peak loads of the morning, especially Monday morning. Instead of the oncoming heavy flow pushing stale primary effluent to the aeration tanks at a high rate, the primary effluent gradually becomes stronger and does not in any way resemble a shock load.

It has always been the practice to return digester supernatant to the first aeration unit, but before recirculation was tried only a portion of it could be handled with the mixed liquor, the remainder going to a lagoon. With recirculation, however, all supernatant, regardless of its quality, can be handled by the secondary process with no ill effects being registered in the final tanks or the final effluent.

Summary

The benefits of recirculation in this particular case can be summarized as follows:

1. Practically no disagreeable odors at any time, and no discoloration of paint as a result.
2. Healthier activated sludge, the result of fresh primary effluent.
3. Better appearing final tanks, which produce a healthier return sludge and a better looking effluent.
4. Secondary process condition such that it can handle all digester supernatant regardless of its condition.
5. A happier operator because of better operating conditions throughout the plant.

CLEANING DIFFUSER PLATES *

By J. Samson

Manager, Bruma Sewage Treatment Works, Johannesburg, South Africa

This paper concerns a method developed in July, 1949, for cleaning the sintered alundum diffuser plates at Johannesburg's Bruma activated sludge plant. All the methods for which accounts were available either had been tried previously or were rejected as being inapplicable.

At the Bruma plant, the shutdown was necessitated as much by extensive failure of the ¾-in. galvanized iron air leads to the diffusers as by the clogging of the plates. All indications that the plates were seriously obstructed were present, however, including increased air pressure, very poor air distribution with air belching in many parts of the channels, and slow but definite deterioration in effluent quality.

Corrosion of Diffuser Air Leads

Although the condition of the air leads was just another example of ferrous metal corrosion at the water-air interface, there were a few points of interest. Each aeration unit at the Bruma plant comprises four channels; one is used for reconditioning return sludge and the remaining three for aeration of sewage. A ring of grease collects around the air leads at the water-air line and immediately above the average sewage level in the sewage aeration channels, but not around the leads in the reconditioning channels.

Corrosion was noticeably more rapid and further advanced in the reconditioning channels than in the aeration channels, although over the years corrosion had advanced to the point where replacement of the air leads was warranted. Many of the air pipes were so badly corroded at the water level that they broke when being removed. Beneath the liquid level the pipes were scarcely affected, except in the channel where fresh liquid mixed with the reconditioned activated sludge. Here the pipes were badly pitted from the bottom upwards.

As new piping was in scarce supply and expensive, a coat of bituminous paint was put on the lower portion before replacing them. All broken pipes were jointed by means of 6-in. lengths of 1-in. rubber hose (pipes are ¾-in. in diameter). Until the number of pipes corroded through was excessive, temporary repairs had been effected by hacksawing out the corroded section and rejoining the remaining pieces with rubber hose and clamps.

* Extracts from "Cleaning Aeration Plates in the Diffused Air System of Activated Sludge Treatment of Sewage," presented at a meeting of the South African Branch, Institute of Sewage Purification, Johannesburg, South Africa, Apr. 13, 1950, and published in *Public Health*, **14**, 7, 219 (July, 1950).

Condition of Diffuser Plates

Considerable trouble was experienced in removing the plate holder frames, as they had been cement grouted into the channels. Many years previously the plates had been removed from the frames for cleaning without removing the latter, but replacement was found to be a very awkward procedure and resulted in breakage of many plates by men standing on them and dropping tools on them. Broken screws were difficult to remove and replace. In addition, balancing of the four plates in each frame to give uniform diffusion was not possible. In the present instance, it was found that by immersing the entire frame in the hot water from the gas-engine cooling jackets, screws and plates were easily removed without any damage.

The pores of the plates were found to be clogged with mineral oil from the air compressors, some rust from the piping, and some calcium carbonate derived from the hardness of the water.

Method of Cleaning

Before the exact nature of the deposit had been established, a few of the recognized reagents were tried out. Solutions of hot caustic soda ash, as well as a mixture of soda ash, soft soap, and sodium silicate, were used in an oil drum, with the plates suspended on hooks from pipes laid across the top of the drum. None of the treatments were effective in removing the deposits.

Dilute hydrochloric acid treatment of single plates was also ineffective. Petroleum ether was also unimpressive in the lack of complete removal of the deposit, quite apart from the obvious expense of such a process of solvent extraction.

When it was shown that the deposit was essentially mineral oil from the single-stage reciprocating compressors, heating of the plates over a gas flame was cautiously attempted. The oil was completely removed by distillation and/or combustion, but plates cracked rather easily during both the heating

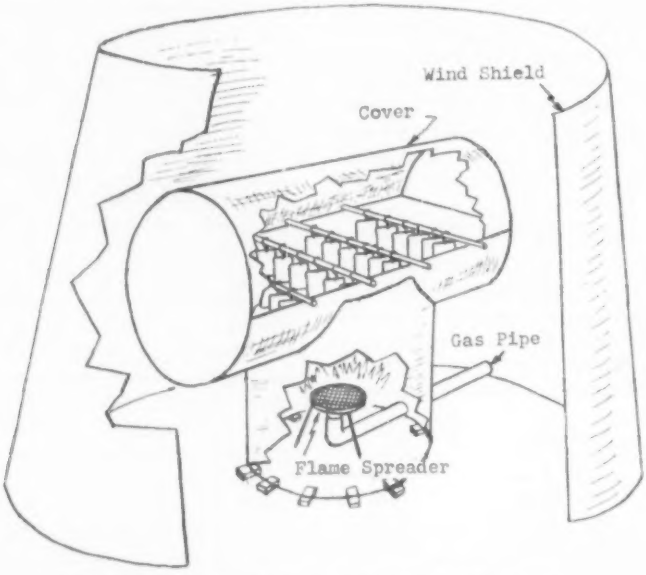

FIGURE 1.—Hot air oven for cleaning diffuser plates.

and cooling, unless both were done very gradually.

It was decided, therefore, to try removal of the oil deposit by distillation rather than burning. After some preliminary trials the following apparatus and procedure were built up and used to treat all the plates from one unit, amounting in all to 1,576 plates.

A segment was cut out of the side of an oil drum, leaving the ends intact; 48 plates were suspended in this air oven by wire hooks (through the screw holes) from pipes laid across the diameter of the drum. This oven was mounted on a second oil drum, cut away as shown in Figure 1. A sludge gas burner was fitted in the lower drum. Uniform heating, as well as protection from the wind, was secured by placing sheet metal over the open top of the oven and as a screen around the windward side of the whole apparatus.

The plates do not come into contact with the flames. However, they can be raised to a high temperature and cooled in the same apparatus by reducing and finally shutting off the gas flame as gradually as is required. An 8-hr. working day is required to remove all the oil and allow slow cooling overnight.

The brass screws for securing the plates in the frame were cleaned in the same operation by placing them on a wire screen. While one batch of plates was heating, a laborer had time to wire-brush another batch, which had already cooled off.

This procedure was considered economical, as the cost of the apparatus and the gas consumed was negligible. Although only 48 plates were treated at a time, the work was a part-time job for one laborer.

Before being restored to use, the plates were fitted temporarily into frames and tested in a shallow bath. By visual inspection, approximately equal diffusions were achieved by trial and error with combinations of plates.

INTERESTING EXTRACTS FROM OPERATION REPORTS

It's well to lay out a schedule for the day's work, but it's more important to do the work.

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

Annual Report of the Sewage Disposal Commission of the City of New Britain, Conn., for Year Ended March 31, 1950 [1, 2]

By John R. Szymanski, *Superintendent*

The treatment process (Guggenheim) includes bar screens, triturator, grit settling tank, primary settling tanks, Parshall flume, dosing tank, aeration and mixing tanks, and final settling tanks with sludge return to the aeration tanks. Sludge treatment and disposal includes sludge aeration and storage tanks, chemical conditioning, vacuum filtration, and incinera-

[1] For last previous extract see *Sewage Works Journal*, **19**, 3, 502 (May, 1947).

[2] Recipient of FSWA 1950 Hatfield Award (previous winner) for plants between 10,000 and 100,000 population.

tion or lagooning. Designed to handle 9 m.g.d., the plant was placed in operation May 1, 1937. No major changes or additions have been made since, although the load for the past several years has been increasing rapidly to its present 11.25 m.g.d. volume from an estimated equivalent population of 80,000.

Repairs and Maintenance

Repairs and maintenance operations were accomplished during the year as required or scheduled. Most of the repairs consisted of normal replacement of worn-out parts or small unit assemblies. After a detailed study, the triturator teeth were tipped with carboloy. Since then they have been performing satisfactorily. An extensive painting schedule was carried out by plant personnel without outside help, in accordance with a policy adopted before the beginning of the year.

Table I is a summary of the 1949–50 operating data:

TABLE I.—Summary of 1949–50 Operating Data, New Britain, Conn.

Item	Average	Item	Average
Population served, equivalent	80,000	Hours run monthly	342
Sewage flow (m.g.d.)	11.25	Lb. wet filter cake produced, total for yr.	15,631,619
Daily max. (m.g.d.)	14.9	Lb. dry solids in cake, total for yr.	4,930,452
Daily min. (m.g.d.)	7.5	Rate (lb. per sq. ft. per hr.)	6.01
Screenings removed (cu. ft. per mo.)	1,457	Ash produced from sludge burning, total (cu. ft.)	35,705
Grit removed (cu. yd. for year)	180	Fuel oil used for heating and sludge incineration, total (gal.)	59,653
Grease skimmings removed (cu. ft. per mo.)	852	Suspended solids (p.p.m.):	
Chemical dosing:		Raw	209
Lb. copperas per mo. (when used)	34,764	Primary influent	241
Lb. chlorine per mo.	7,731	Primary effluent	159
Lb. Ferrisul per mo. (when used)	26,118	Mixed liquor	878
Air used (cu. ft. per gal. sewage)	0.12	Final effluent	42
Per cent of returned sludge	9.7	5-Day B.O.D. (p.p.m.):	
Excess sludge wasted to primary tanks:		Raw	187
M.g. per month	3.17	Primary influent	214
Primary sludge removed for filtering (gal. per mo.)	654,426	Primary effluent	156
Chemicals for conditioning of sludge:		Final effluent	52
$FeCl_3$ (lb. per mo.)	8,222	Total iron (p.p.m.):	
Wet Prestolime (lb. per mo.)	110,678	Raw	22
Vacuum filters:		Final effluent	8
Days run monthly	17.7	Expenditures (dollars)*	114,677.87
		Per m.g. for operating expenditures	24.68

* Includes $3,375.00 interest on bonds and $10,000 payment on bonds.

Nineteenth Annual Report of the Aurora, Ill., Sanitary District Sewage Treatment Plant for the Year 1949 [1, 2]

By Walter A. Sperry, *Superintendent*

The year 1949, as a whole, was on the negative side as compared with many former years. Total flow was 9.2 per cent less than for 1948; the B.O.D. and suspended solids contents of the raw sewage were, respectively, 17 and 13.7 per cent less than in the previous year. The total poundage of

[1] For last previous extract see *Sewage Works Journal*, **21**, 1, 149 (Jan., 1949).

[2] Recipient of FSWA 1950 Hatfield Award for plants serving 10,000 to 100,000 population.

primary sludge was consistently 15.3 per cent lower, which was reflected in the 23.7 reduction in gas volume obtained. Oxygen demand removal in the effluent discharged to Fox River was only 71.5 per cent (compared with 82.2 per cent in 1948), due partly to the quality of the sewage treated. Of the total flow, 24 per cent received only primary treatment because of flow levels in the river or interrupted operation of the filters and secondary tanks for repairs.

Plant Costs

The 1949 operating cost totalled $52,455.45, or at the rate of $22.64 per m.g. ($0.9366 per capita). With administration included, the unit rates were $27.61 per m.g. and $1.14 per capita. If power had been purchased, rather than plant-derived, the operating cost would have been increased by $2.46 per m.g.

Total operating cost was 13.8 per cent greater than in 1948, mostly due to purchase of new equipment and addition of one man for work on grounds, sludge beds, and general maintenance.

Engine Performance

The gas-driven pump engines have completed 13 years and 9 months of service; the generator engines have completed 9 years and 2 months of operation. Performances for these periods have been 93.1 per cent and 100 per cent for the respective equipment.

Improvements and Additions

Installation of the "diffusair" aeration process in No. 1 clarifier was completed during the year and operated sufficiently to make all adjustments. Normal operation will be inaugurated during the summer season of 1950.

In July, the office was equipped with an air conditioning unit. This greatly improved working conditions, which had been bad due to the office floor being immediately above the furnaces in the gas room below. Plans also were completed for air conditioning the laboratories following the anticipated building changes and additions in 1950.

A swamp area on District property adjacent to the sludge and grit disposal grounds was eliminated by filling. This not only adds more storage area, but also eliminates a definite nuisance.

A sound-proof room was constructed in the present garage and around the two 250-c.f.m. blowers providing air for the new aerators. The garage, when converted into a shop as anticipated would have been intolerably noisy.

Sludge Digestion and Drying

Digester operation for the year was normal and followed the plan of applying all primary sludge to the first-stage digester and all secondary sludge, on alternate days, to the two secondary digesters. Of all the gas produced, 78.8 per cent was generated in the first-stage digester. However, this tank has not been cleaned for five years, so that a complete cleaning is necessary.

During the year a total of 31.25 sludge beds (174,225 sq. ft.) were cleaned of 1,209,850 lb. of equivalent dry solids. The sludge cake averaged 5.1 in. thick; 2,378 cu. yd. was removed to the storage pile at a cost of $1,577.57, or $0.575 per cu. yd. On the dry basis, therefore, the actual air-dried sludge averaged 440 lb. per cu. yd., which indicates a removal cost of $2.61 per ton.

Maintenance

The old Chevrolet 1-ton truck was replaced with a 1½-ton International truck. Plant changes included a steel plate body bottom and pipe-carrying racks on the right fenders. A switch control box for the lighting circuits in the clarifier house was replaced. The old equipment had been completely destroyed by the dual ravage of moisture and hydrogen sulfide. New grate bars

were installed in the screenings incinerator.

Maintenance painting of the underwater steel work of clarifier No. 4 was begun. This is a four-coat plastic-type paint job. The paint used is manufactured by the Merchants Chemical Company and sold under the trade names of "Dyna-Clad" and "Dyna-Flex." The protective properties of this paint will be watched with the greatest interest, as 8 × 8-in. test plates

TABLE II.—Summary of 1949 Operation of the Aurora (Ill.) Sanitary District Sewage Treatment Plant

Item	Average
Rainfall (in.)	34.15
Tributary population (estimated)	56,000
Sewage treated (m.g.d.):	
Total	6.33
Complete	4.81
Primary only	1.52
Screenings (cu. ft. per m.g.)	1.88
Grit (cu. ft. per m.g.)	2.11
Grease and scum (cu. ft. per m.g.)	0.55
Suspended solids (p.p.m.):	
Raw	182
Settled	84
Filter effluent	56
Final	32
Reduction (%)	82.4
Pounds per capita in raw	0.173
B.O.D. (p.p.m.):	
Raw	112
Settled	72
Filter effluent	30
Final	21
Reduction (%)	81.2
Pounds per capita in raw	0.106
Oxygen consumed (p.p.m.):	
Raw	48
Settled	40
Filter effluent	29
Final	27
Reduction (%)	43.7
Nitrogen as free NH_3 (p.p.m.):	
Raw	8.5
Settled	8.9
Filter effluent	3.2
Final	3.0
Nitrogen as total org. N (p.p.m.):	
Raw	19.5
Settled	17.0
Filter effluent	11.7
Final	9.8
Nitrogen as NO_3—final eff. (p.p.m.)	7.0
Raw sludge:	
Total solids (%)	3.9
Volatile solids (%)	69.0
Equiv. dry solids pumped (lb./day)	212.0
Final settling tank sludge:*	
Total solids (%)	5.4
Volatile solids (%)	54.4
Equiv. total dry solids pumped (lb./day)	42.0
Transfer sludge—1st stage to 2nd stage:	
Total solids (%)	2.0
Volatile solids (%)	52.9
Equiv. total dry solids pumped (lb./day)	109.0
Digested sludge:	
Total solids (%)	10.9
Volatile solids (%)	44.4
Supernatant (from 2nd-stage digesters):	
Total solids (%)	0.30
Volatile solids (%)	48.8
Gas production:	
Cu. ft./lb. volatile matter added	7.92
Cu. ft./lb. volatile matter destroyed	15.30
Cu. ft./lb. dry solids	5.3
Cu. ft./m.g. sewage	6,370
Cu. ft. per capita	0.721
Gas produce in 1st stage (%)	78.8
Gas composition:	
CO_2 (% Vol.)	31.8
O_2 (% Vol.)	0.4
H_2 (% Vol.)	2.6
CH_4 (% Vol.)	64.2
N_2	0.9
H_2S (p.p.m.)	125
B.t.u. (net)	587
Gas engine earning statement:	
Total engine investment ($)	18,321.50
Net earnings in 1949 ($)	4,852.73
Total net earnings—165 months ($)	68,139.49
Plant operating costs ($):	
Payroll	33,966.31
Retirement fund	3,383.05
Interceptor system	1,077.86
Truck	1,612.95
Office	429.68
Laboratory	216.13
New equipment	4,797.58
Repairs	2,389.71
Gas engines	949.57
Miscellaneous	3,612.61
Total	52,455.45
Total cost per m.g.	22.64
Total cost per capita	0.94
Total disbursements (operation, interest, bonds, etc.) ($):	
Per m.g.	49.62
Per capita	2.05

* To 2nd-stage digesters.

continuously exposed for 21 months in the raw sewage channel came through this test period in perfect condition. The effectiveness of the present experiment, however, may be marred somewhat by the fact that previous maintenance coatings on this steel work consisted of a bituminous material, which could not be completely removed. It is suspected that the solvent effects of the new paint vehicle on the bituminous material beneath may account for some difficulties.

The gas collector dome on digester No. 3 finally became so corroded it became necessary to repair it. This was done by encasing the dome with a thin reinforced concrete shell, as was done satisfactorily many years ago on digester No. 2.

The tipping-bucket sludge meter was overhauled and fitted with a new shaft. Some splash plates were attached to the under side of the inspection lids, which has helped in keeping operation of this equipment much cleaner on the outside.

Drain valves were placed at either end of the sludge line flushing system to carry these lines over the winter and as a protection against freezing.

During the summer the filter dosing chambers were cleaned out, the pipe work repaired in two or three places where corrosion had done its work, and the chambers were repainted with a heavy coal tar base paint. As considerable frost damage had occurred around the edges of the large doors on top of the dosing chamber covers, before cold weather set in the doors were insulated with a layer of straw held in place by tar paper and weights.

United Wallpaper Company Wastes

The United Wallpaper Company's operation was interrupted twice during 1949, once in midsummer for a vacation period, and in the fall the plant was shut down for the month of November. An examination of this mill's waste, as composite weekly samples, was made for 43 weeks of the year. An analysis of this work indicates that for the period of test the average suspended solids received in their chemical precipitation plant was 7,480 p.p.m. and the suspended solids discharged in the effluent to the District interceptor was 900 p.p.m., a removal of 87.9 per cent. The average flow of waste per week was 0.287 m.g. which indicates a waste discharge of 1.07 tons of clay per week. This was a larger load of clay discharge than we think desirable. However, the plant absorbed it without undue stress. The clay incorporated in the primary sludge proved to be a definite advantage in the digesters by lengthening the periods between digester discharges and because of its "loading" effect. Digester discharges were increased from 45 to 50 days in 1946 and 78 days in 1947, to 99 days in 1948 and 106 days in 1949. These longer digester "runs" between discharges greatly reduced the problem of sludge removal from the sand beds. The disadvantage of this clay addition was that the appearance of our effluent to Fox River was definitely "smoky" due to finely divided clay. We miss the polish and sparkle of our former effluent.

Table II contains a summary of operation data for 1949.

NUCLEAR FISSION OPERATIONS AND THE WASTE TREATMENT PLANT OPERATOR

By George A. Rhame

Sanitary Engineer, Division of Water Pollution Control, State Board of Health, Columbia, S. C.

There have appeared recently in *Sewage Works Journal* two very interesting articles (1)(2) dealing with the problems of the disposal of wastes from nuclear fission operations, as well as a number of concurrent discussions of various phases of the subject in general-interest publications (3)(4)(5). These combined to cause considerable speculation by the writer about the specific problems involved, particularly as related to the operation of any such waste treatment plant.

Digging around in various publications, which happened to be at hand, brought together considerable information on radioactivity and nuclear fission procedures, which might be of interest to waste treatment plant operators. In extremely general, nontechnical terms, the pertinent points may be described as follows.

Basic Concepts

Natural, spontaneous nuclear fission is the well-known process by which certain elements emit various particles and forms of energy and are converted to other elements. Everyone who has been exposed to high-school chemistry has encountered the chain of reactions by which uranium eventually becomes an isotope of lead. The statistical rate at which this natural fission occurs is different for each radioactive element; so far it has resisted all human efforts to cause it to vary. The duration of any radioactive substance is generally defined in terms of "half-life," which is the period of time required for one-half of any given mass of material to be converted to another elemental form by radioactive disintegration (nuclear fission). Half-lives of various elements have been found to vary from billions of years to fractions of seconds.

The principal emissions of radioactive elements are:

1. Gamma rays—the equivalent of exceedingly high-voltage X-rays, having the ability to penetrate considerable distances through solid material. They cause much damage to living tissue by ionization of cell contents. (It is this effect which is used to treat cancer.)

2. Beta particles—ordinary electrons. These particles have very low penetrative powers, but are capable of causing cell damage when emitted within the body because of ionization.

3. Neutrons—comparatively massive particles whose speed and penetrative ability varies with the source. (A few low-speed neutrons are always present in the atmosphere.) Those with sufficient speed to penetrate the body are capable of great damage due to ionization and other effects. They can cause fission by entering an atomic nucleus.

4. Alpha particles—helium nuclei (helium atoms minus their outer electrons). These particles have very little penetrating power, but will cause serious damage from ionization effects when emitted within the body.

A chain reaction is one in which the neutron emitted by one atomic fission enters the nucleus of another atom, causing it to fission in turn, and so on. A great quantity of heat is released at the same time. This, together with the gamma rays and neutrons, accomplishes the effects of the atomic bomb. The only known natural material capable of accomplishing a chain reaction rapidly enough for military purposes is that isotope of uranium having an atomic weight of 235, generally known as U235. As it is present to the extent of less than 1 per cent in natural ura-

nium, which consists largely of U238, its separation on a large scale presented an industrial chemistry problem of unprecedented proportions; especially as most of the work had to be done by completely automatic machinery, due to the dangerous radiations.

Fortunately, it was found possible to set up a chain reaction whose rate could be controlled by using the "atomic pile," or "nuclear reactor," a large and expensive gadget, the mechanics of which are beyond the scope of this paper. The atomic pile was originally designed to take advantage of the fact that in a controlled reaction the neutron resulting from the fission of U235 can be made to transmute such elements as U238 and thorium to other elements capable of taking part in a bomb-type fission. The pile also may be used to prepare various other radioactive isotopes for industrial, medicinal, and other uses and may serve as a source of heat for generating electricity for public use or for driving such things as warships and submarines.

Fission Waste Treatment

The concern of the waste treatment plant operator is with the waste products of pile operation and isotope separation, although some idea of the water treatment plant operator's worries about the relation of the atomic bomb to public water supplies will be obvious. The most voluminous waste arises from the necessity of cooling the piles lest they melt themselves down. This is done quite conventionally with water or air, although the latter is ignored herein.

Cooling water presents the greatest source of trouble in the whole situation—that of uncontrolled radiation from almost any element exposed to neutron bombardment for any length of time. Most elements have radioactive isotopes, over 600 being known at present. Hydrogen and oxygen are practically immune to this effect, but the mineral matters contained in natural waters are quite susceptible. These isotopes may be removed with considerable success by ordinary water treatment processes; however, in time, the filter beds would become radioactive to a degree dangerous to the operators. Furthermore, the presence of even a very small amount of radioactive materials in potable water would result in the build-up of a dangerous concentration within the bodies of those using it. It must be remembered that very small quantities of such materials are dangerous within the body.

Fortunately, lagoons are capable of good results if designed to hold the water long enough for the more active short-lived materials to exhaust themselves. The process is considerably aided by the fact that radioactive materials tend to concentrate in the normal water plankton and algae without harming them. Eventually the bottom of such a lagoon, and any living creatures which feed on the plankton and algae, become quite "hot."

Observation of the concentration of radioactive materials in plankton naturally suggested the possibility of using the activated sludge process for treatment of these wastes, particularly the more concentrated ones. Laboratory-scale pilot plant tests at Los Alamos, N. Mex., showed that results would be very good, although it is easy to imagine that operation of such a plant would be beset with a number of peculiar problems.

The treatment process described by Ruchhoft (2) presents some unique features. It was found that consistently good results required long aeration periods. Therefore, the plant was operated on a batch basis with 23-hr. aeration followed by 1-hr. settling. Wastes would be collected in an equalizing tank prior to treatment. Presumably wastes would be carefully segregated and controlled to keep those exhibiting high-level radioactivity at relatively small volumes. Use of a

storage tank would also permit chemical neutralization, when necessary, and provide a safeguard against the possibility of accidental spills of dangerously radioactive materials likely to get into the waste collection system of the atomic plant. As a further precaution the treatment plant would consist of two stages in series, each complete as described above.

To maintain the sludge in an active condition it would be fed as required, using either domestic sewage or some nutrient material. Investigations are being made into the possibility of using some cheap foodstuff. All waste sludge would be vacuum filtered and disposed of by burial or otherwise. (The process sounds highly expensive, but is expected to be more economical than methods of waste disposal in use at present.)

Operation of Plant

From the relatively meager information presently available it is possible to make some interesting speculations about a full-scale treatment plant and its operation. For instance, the efficiency of the pilot plant was measured in terms of alpha-particle emission from the influent and effluent.

This suggests that the most dangerous radioactive material in the waste being treated is one of the heavy metals. Their removal from the waste by this type of treatment may possibly be due to the same factors causing heavy metals in sewage to collect in the sludge of an ordinary activated sludge plant, except that here their physical concentration is too low to cause chemical toxic effects. As these materials are particularly dangerous when taken into the body, due to the cumulative effects appearing at very low concentrations, all equipment containing wastes or sludge would have to be totally enclosed to eliminate the possibility of the operators coming into contact with wastes, spray from aeration tanks, or waste sludge. Because of the danger of these heavy metals being absorbed through an open cut or scratch, all piping, pumps, etc., should be arranged for a minimum of mechanical manipulation. (It has been reported that among Manhattan Project personnel anyone who received a cut in the hand while working with plutonium was immediately given a high amputation.) Furthermore, there is always the factor of induced radiation in the actual plant structures and equipment.

All this suggests the possibility of using the Aero-Accelator or some similar equipment; with sufficiently rigorous controls over waste volumes these devices would be quite small and could be constructed of some relatively cheap material for economical replacement and disposal when they became contaminated enough to be a radioactive waste themselves. There might even be some advantage to adapting the "bio-precipitation" process to this type of equipment.

In the matter of "feeding" the activated sludge, it appears that the use of foodstuffs rather than sewage would be highly desirable because it would be possible to accurately control its quantity and quality. It must be remembered that the loss of any quantity of sludge (due to improper settling), which would contain relatively concentrated radioactive material, would be the equivalent of a sizeable spill of untreated waste to the receiving stream and would be considered quite hazardous.

Sludge Handling

Sludge handling in such a plant would be a particularly difficult problem, due to its high content of dangerous material. Ruchhoft states that the raw wastes treated in the pilot plant had an alpha count of 100,000 per liter, and that the plutonium concentration in the dried sludge was 700 times as great as in the untreated waste. (An "alpha count of 100,000 per liter" means that that number of alpha par-

ticles were released each second from a liter of waste.) It appears not unreasonable to expect a count of 400,000 in the wet sludge. Although the writer became lost among the various standards for safe exposure and units of radiation, the latter number appears to represent a fairly dangerous level of activity. Sludge handling equipment would probably have to be replaced after rather short periods of use, because of induced radiation. Separate sludge concentration would be inadvisable, because of the extra handling required. Vacuum filtration equipment would have to be operated by remote control in a completely shielded area. Ultimate sludge disposal would be by burial in controlled areas, or by dilution in concrete blocks and dumping at sea. Then again, perhaps the entire plant would be shielded and operated by remote control.

Lastly, in the matter of the laboratory control of such a treatment plant there are some unusual considerations. All work involving sludge would have to be done with shielded, remote control equipment and many of the conventional tests would be relatively immaterial—for instance, B.O.D. and suspended solids of the effluent would be superseded by the alpha count. Some very interesting control problems would arise from the necessity of regulating, in the effluent, the quantities of dissolved organic compounds, which would contain radioactive forms of carbon and nitrogen. Consider, however, the joy of working in a laboratory where routine replacement of all glassware and most other equipment (due to induced radiation) would insure a continuous supply of new equipment in tip-top condition!

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MAINTENANCE AND INSPECTION OF EQUIPMENT *

By W. H. H. Putnam

General Manager, Birmingham Waterworks, Birmingham, Ala.

The best of plants will not continue to give dependable service unless properly operated and carefully maintained. A major argument for operation reliability is that its lack costs actual, cold, hard cash. It may cost just as much to replace a bearing before it fails, but if a breakdown occurs at the wrong time—and it seems that most of them do—the cost of making emergency repairs is almost invariably greater than it would have been if they had been made in the regular course of business and when the operator wanted to do the work.

Maintenance is not repair work after a failure; it comprises the preventive measures taken to reduce the amount of repair work caused by failures, or even to eliminate them entirely.

* Presented at 1950 Annual Meeting, Alabama Water and Sewage Association; Auburn, Ala.; June 6–9, 1950.

Importance of Good Inspection

In this regard, advance notice of trouble is provided by inspection, and thoughtful inspections by a conscientious and observant person are far more valuable than careless routine inspections frequently made. The operator will doubtless make an inspection of sorts on all pieces of operating equipment several times a day. This sort of inspection usually includes only checking the oil in the bearings, checking bearings or pump glands for heat, listening to the sound of the machine, etc. Regular and more detailed inspections should be scheduled and a system established that can be continued in a reliable manner.

Records Also Necessary

Records, whether on paper, cards, or pamphlets, are necessary to do a systematic job of keeping the plant in good running order. These records should include detailed data on each machine and a brief record of repairs to each machine.

Under the first heading, a parts list and operating and maintenance manual for every single piece of equipment in the plant is of primary importance. Sooner or later, some of the parts in the various machines will have to be replaced. Drawings or descriptions given in the parts list and manual will make this job easier. It is also infinitely easier and quicker to get repair parts if they can be identified correctly by name and part number. It has been found to be of tremendous help to have a folder or envelope for each major unit, so that when an inspection is made or trouble develops, that particular folder can be picked out to have at hand all of the parts lists and available literature.

Any manufacturer will be glad to send the parts lists and manual for any motor, pump, switch, or other machine or apparatus upon request. To secure this material it is only necessary to request it, giving the type of apparatus and the data on the name plate. Data on old equipment is, however, sometimes hard to get.

The second of the tools is a simple card or sheet, on which is listed certain pertinent data on each machine, and a record of all inspections and repairs. Many who are familiar in detail with day-to-day operation are too prone to carry these details around in their heads, rather than keeping written records. A simple card system, kept up to date, is worth more than a bale of elaborate forms so bunglesome that no one will ever try to keep them up after the first few weeks.

A card or sheet can be prepared to fit the particular plant conditions encountered. Such a card can be developed to cover each motor, pump, and other piece of equipment, and should contain all of the name plate data on the particular machine or device. The back side of the card should be available for listing inspections, as well as repairs made to each machine. The inspection sheet should also contain a complete list of things to be checked by the inspector. This serves as a check list and helps to keep him from overlooking some important point.

Fits into Work Schedule

Inasmuch as work done before a breakdown can be done at a time of one's own choosing, it is, of course, possible to schedule these inspections and any preventive maintenance work found necessary to fit other work schedules. Normally, all motors and pumping equipment should be completely dismantled and inspected during expected periods of low load. Some types of drives, such as gasoline engines and diesels, may require more frequent inspections, depending on the length of time they are in operation. However, it shouldn't be hard to set up an inspection schedule for each particular unit. Helps are available in the form of booklets published by the various manufacturers.

An important thing to remember is that nobody is going to keep your plant up for you; it's your responsibility, and if it breaks down you are the one that will have to crawl out in the middle of the night to get it running again.

Some Things to Look For

Motors

Under the heading of motors, the most important points to be considered are the bearings, windings, couplings or pulleys, and brushes and commutators. Bearings, of course, should be inspected for wear and the sealing device, usually a felt ring, should be kept in good order to prevent the leakage of oil. Any leakage of oil or grease out the inboard end of the bearing will affect the condition of the windings.

Motor windings should be kept free of dirt and grease and should be checked with an insulation testing device called a "megger." This is a small high-voltage generating device, with a scale graduated in ohms to measure the resistance of the insulation. Insulation of high resistance is, of course, good; and insulation having a low resistance is, of course, apt to fail.

Couplings should be tight on the shaft; the rubber bushings and the coupling bolts should be free from wear. Brushes should be of proper grade and should have the proper amount of tension on them. Commutators should be kept smooth and clean and when found to be rough, should be trued up by machining.

Controls

There are so many types of control equipment that only general remarks can be made regarding switches and controls. They should be kept free of dirt and foreign matter. Excess heating of contacts or coils is a sign of trouble, which should be corrected. All moving parts, of course, should be set to work as freely as possible and without binding. If the contacts show excessive wear or binding, they should be cleaned or replaced. Plain vasoline is a good lubricant for contacts having sliding action. Proper contact pressures should be maintained and arcing eliminated. All loose connections, wherever found, of course, should be tightened up. A loose connection is apt to induce high resistance and heating in the connection. In oil switches, the proper oil level should be maintained and oil should be changed when needed. Because the oil acts as a quenching medium, it should be free of foreign matter, which will serve as a conductor of the current. Any piece of control equipment which has protective devices, such as under-voltage relays, overload relays, and the like, certainly deserves to have these devices in satisfactory operating condition.

Pumps

There is not much in a centrifugal pump to be kept in good condition, but it is important that its condition be maintained by periodic inspections. Bearings, of course, should be inspected and kept in first-class condition. Gland sleeves will wear and should be replaced or repaired when they become worn. Both leakage and overheating are indications of trouble in the sleeves. Every pump manufacturer has a different type of wearing ring or labyrinth ring, but after long periods of service these rings are apt to leak water back from the high-pressure side of the pump to the suction side, particularly when handling liquids containing sand or other grit. Some idea as to the condition of these rings can be obtained without even taking the pump out of service. Any pump manufacturer will be glad to furnish a shop test curve on the particular pump, which will give the delivery at various pumping heads. If the pump is not pumping as much water as is indicated by the curve at a

particular head (the pump speed being correct), there is a strong indication that the wearing rings need replacing. It may be that the impeller is worn, but this can be determined by visual inspection.

Bearings

Another important feature in maintaining any type of machinery is the lubrication. Ball bearings and roller bearings are being used more and more on pumps and motors, as well as other types of equipment. These types of bearings are usually lubricated by reasonably heavy grease and if a pressure type fitting or cup is provided, many operators have a tendency to over-lubricate. This has two definite disadvantages. Over-lubrication can cause the bearing to run hot; it most certainly will result in forcing grease out of the bearing, possibly onto the motor windings.

TIPS AND QUIPS

Smooth Running Motors

Trouble in getting a new motor installation running right can show up in a variety of ways, one of which may be vibration. If this problem is encountered, an immediate checkup is indicated on the various factors that are keeping the job from running smoothly. The following suggestions on what to look for are given by J. H. Jones, of the Electric Machinery Mfg. Company, in a recent issue of *"E-M Synchronizer"*:

1. Run the motor disconnected from the load and check it as a unit.
2. Make sure the motor feet are solid by loosening the hold down bolts and checking for vibration of the motor foot relative to the base. Be sure the motor feet are properly shimmed before taking up again on the hold down bolts.
3. Check to see that wedges between base and foundation did not slip during grouting and that all voids beneath the base are full of grout.
4. Check the base itself for true and level.
5. Handle shaft and motor carefully to avoid springing the shaft.
6. Check alignment between motor and driven equipment. Make sure that shafts are level and in proper position with each other.
7. Check coupling for proper size and for operating condition. See that the key is about the same length as the keyway in the coupling, and not too long.
8. Poor grouting and base installation tend to show up more quickly under coupled operation, particularly if high starting torques are required or the load is a pulsating one.
9. Analyze the driven load. Unbalanced operation, worn gears, etc., may be the entire cause of the trouble.
10. Notice whether vibration occurs while bringing a synchronous motor up to speed (usually mechanical unbalance or misalignment), or after synchronizing (may be a partially short-circuited field winding).

Maintenance Item

Have trouble getting new tight-fitting bushings into place without stress and strain? The March, 1950, issue of *The Accident Record*, published by Western Electric, reveals a simple trick to ease the way—chill the bushing with dry ice, then slip it into place.

Metal Crack Inspection

What is claimed to be a revolutionary non-destructive chemical process of

checking metal parts for surface cracks and flaws of even the minutest extent has been announced by the Dy-Chek Company, 1515 East Broadway, Hawthorne, Calif.

To use the method, the metal surfaces are thoroughly cleaned and dried, a special penetrant dye is applied and allowed to stand for a few minutes, the excess dye is removed, and a "developer" is applied. Penetrant remaining in any crack or discontinuity will react with the developer within a matter of a minute or so to give vivid visual evidence of the location and extent of the opening.

More Credit

The editorial "Credit Due—Credit Given" (THIS JOURNAL, **22**, 8, 1069; Aug., 1950) has brought to light two other instances where pollution abatement efforts of local authorities have received recognition from "clean stream" organizations. One, apparently, even antedates the "first" mentioned in the previous article, as the Illinois Division of the Izaak Walton League presented its sanitation award to the Sanitary District of Chicago on October 13, 1949. The citation in this case was for District accomplishment in providing complete treatment of up to 90 per cent of the sewage in its area.

Another Illinois Division sanitation award was presented on September 15, 1950, to the Greater Peoria Sanitary District for its success in stream pollution abatement.

Congratulations to both the "old" and the "new" recipients!

Sewage Tank Pumping

During the past year, publications of more than one State Health Department have called attention to the "racket" of pumping units contacting cities and individuals to pump out the contents of sewage treatment devices at a rate of so much per pound, gallon, or ton. Some good examples of what can happen are reported in a recent issue of *The Clarifier*, published by the South Dakota Department of Health, as follows:

"One such outfit was contacting farmers to pump septic tanks at 10¢ per pound. The minimum size tank approximates 500 gal., or about 4,165 lb. At 10¢ per pound, it would cost a little more than $400 to pump this size tank. One rancher recognized that this cost was probably excessive, and finally negotiated to contract the job for $50.

"Another case called to our attention concerns a municipality which was approached by a pumping outfit who wanted to pump the 'sludge' for $15 a ton, or ¾¢ per pound, quite a bit cheaper than the above illustration, but read below for the total cost. The Imhoff tank of this particular city was of such a size the pumper indicated the cost would not exceed $500, but the city was tendered a bill for $3,500, representing a pumpage of 233 tons of 'sludge.' The total capacity of the particular tank was 15,400 cu. ft., or approximately 340 tons of liquid."

Maybe the pumping outfits have discovered "recirculation"!

Preaeration Data Needed

Although increasing use of preaeration or "air-flocculation" in sewage and industrial waste treatment plants points to the recognition of its benefits, there is a dearth of published basic data on the capacities and limitations of the practice. Nevertheless, it appears from general consideration of this "new" development (see *Sewage Works Journal*, **21**, 4, 748; July, 1949) that the process should prove beneficial to at least some degree in every installation.

This, then, is a plea for superintendents and operators of plants equipped with preaeration facilities to gather as

much data as possible, with a view to evaluation of the specific benefits that result from use of the process. Where the plant layouts permit, comparative studies would be especially interesting and valuable. In addition, an assessment of the economies of the process is urgently needed.

Here is an opportunity to contribute to the advancement of the art, even for the smallest of plants. In addition, the information secured should be useful in appraising your own operation of the process, perhaps even indicating modifications that would otherwise be overlooked. However, regardless of the outcome of your experiments or studies, don't just file the data away. Send it along; your "Corner" will make the information available to others.

Time Saver

If your time is worth anything, the 20-Year Index to Sewage Works Journal will more than pay for itself the first time you use it in looking up an extensive literature on some problem facing you.

Here is the key to the record of the period of greatest progress in the field, in a form that makes it easy to find whatever it is you are looking for. If you know who wrote it or where it was done, the author or geographical sections will locate the article in simple fashion; if not, the subject section is so set up as to give complete coverage of the matter sought.

The 20-Year Index of the Journal is a "must" for every plant, large or small, as well as for engineers, public health authorities, industrial wastes personnel and libraries. The Index is available from The Garrard Press, Champaign, Ill., at $4.50 per copy.

Chemical Brighteners

The next time the radio blares forth a "jingle" commercial about "bright clothes brighter and white clothes whiter," don't turn it off. Listen, and then reflect on what the stuff may do to treatment processes.

Some idea of the effects are contained in a recent issue of *For Instance*, published by American Cyanamid Company. The article says, in part:

"It is known that the brightener absorbs the unseen ultraviolet from daylight and transforms it into visible light. Therefore, clothes washed with soap containing the brightener reflect more light and so look brighter. . . . It seems that quite a few chemicals will change ultraviolet into visible light but not all of them meet the requirements for use in soap. A good brightener must be readily dispersible in water but must also attach itself to the fabrics being washed. . . . Since some people use a hypochlorite type of bleaching agent in the wash, the brightener must also have good resistance to this chemical."

Are we now to have "brightened" sewage? Let's hope that as the use of these compounds increases they will make available enough additional "light" to lead one out of the darkness concerning many process phases. At least they should bring out the "colorful" aspects of wastes treatment!

Proceedings of Member Associations

ARKANSAS WATER AND SEWAGE CONFERENCE

19th Annual Meeting

Little Rock, Arkansas, April 17–19, 1950

A record-breaking registration of 190 members were welcomed to the 19th Annual Meeting of the Arkansas Water and Sewage Conference at the Municipal Auditorium, Little Rock, Ark., April 17–19, 1950. The meeting was climaxed by the Annual Conference Dinner, Tuesday, April 18, at which 200 members and guests heard an address given by the Honorable Sid McMaths, Governor of Arkansas.

The sessions during the afternoon of April 17 and the morning of April 18 were devoted to water works papers.

After the luncheon and business meeting for the Sewage Works Section, in which an address was given by A. H. Niles, president of the Federation of Sewage and Industrial Wastes Associations, concurrent sessions were devoted to pumping and sewage subjects. Papers presented at the concurrent sewage session were as follows:

"Sewer Main Construction and Finance," by Ben W. Dees, consulting engineer, Little Rock.

"Sewer Line Maintenance Equipment," by T. W. Clapham, manager, Little Rock Sanitary Sewer System.

"Modern Sewage Disposal Methods, and Water Pollution Control Program," by H. R. Conway, sanitary engineer, Arkansas Water Pollution Control Commission, Little Rock.

At the business meeting, held after the Annual Dinner on Tuesday evening, the following officers were elected for 1950–51:

Chairman: Elmo A. Lambert, Clarendon.

Vice-Chairman: Cecil A. Brown, Pine Bluff.

Secretary: Harrison Hale, Fayetteville.

HARRISON HALE,
Secretary

NEW YORK SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

1950 Spring Meeting

Jamestown, New York, June 12–13, 1950

The 1950 Spring Meeting of the New York Sewage and Industrial Wastes Association, held at Jamestown, N. Y., was the first meeting under its new title.

After the technical session, the delegates inspected the Jamestown sewage treatment plant and the mobile laboratory of the State Health Department.

Highlights of the Annual Dinner were a welcoming address by the Honorable Samuel A. Stroth, mayor of Jamestown, and the presentation of awards to members.

At the technical session, designed to include subjects of interest to both municipal and industrial representatives, the following papers were presented:

"Waste Treatment Problems in New York State," by R. W. Simpson, sanitary engineer, Gilbert Associates, Inc., Reading, Pa.

"Industrial Waste Treatment—Pilot Plant Operation," by Newell L. Nussbaumer, consulting engineer, Buffalo, N. Y.

"Treatment of Phenolic Plastics Manufacturing Wastes," by Norbert H. Kirchgessner, chemical engineer, Durez Plastics and Chemicals, Inc., North Tonowanda.

"Regulation of Industrial Wastes Entering County Sewers," by James C. Harding, commissioner of public works, County of Westchester.

"Classification-Standards System for Waters of New York State," by A. F. Dappert, executive secretary, N. Y. State Water Pollution Control Board.

"Operation of Field Laboratory Unit in Water Pollution Surveys," by W. W. Sanderson, sanitary chemist, N. Y. State Department of Health.

"Sewer Rental Financing in a Small Community," by Frank Nollett, supt. of utilities, Bath, N. Y.

"Sewer Rental Financing in a Large Community," by John J. Joyce, executive secretary, Buffalo Sewer Authority.

"The Future of Sewage Treatment at Jamestown," by Benjamin Schwartz, director of public works, Jamestown.

A panel discussion on "Operation and Maintenance of Equipment in Sewage Treatment Plants, was presided over by Uhl T. Mann, superintendent, Ley Creek sewage treatment plant, Syracuse. In order to answer practical problems of operation and maintenance, equipment manufacturers were invited to assign experienced technicians to the panel.

RALPH C. SWEENEY,
Secretary

ALABAMA WATER AND SEWAGE ASSOCIATION

Fifth Annual Meeting

Auburn, Alabama, June 7–10, 1950

The Alabama Water and Sewage Association held its Fifth Annual Meeting and Short School at the Alabama Polytechnic Institute, Auburn, Ala., June 7–10, 1950. As initiated at the 1949 meeting, afternoon periods were divided into concurrent water and sewage sessions. A new high in attendance was established with 130 registrations.

After addresses of welcome by R. B. Draughon, president, Alabama Polytechnic Institute, and D. G. Gill, health officer, Alabama State Health Department, the meeting heard a message on Federation affairs by A. H. Niles, president, Federation of Sewage Works Associations.

On the afternoon of June 7, the sewage session was devoted to round-table discussions under the leadership of R. C. Barton, sanitary engineer, Jefferson County, Alabama. Panel members and their assigned topics were:

"Withdrawing, Drying, and Disposal of Digested Sludge," by L. L. Jordan, chemist-operator, Jefferson County, Birmingham.

"Screening and Shredding Coarse Sewage Solids," by Paul B. Krebs, consulting engineer, Birmingham.

"Sewer Cleaning and Maintenance," by E. M. Owen, engineer, City of Birmingham.

Later, the conference delegates enjoyed a fishing trip at the experimental fish ponds of the Alabama Polytechnic Institute, followed by an old-fashioned fish fry.

At the morning session on June 8 papers were presented as follows:

"Selecting and Repairing Water Meters," by Charles D. Hart, assistant superintendent, Bessemer Waterworks.

"Maintenance and Inspection of Mechanical Equipment," by W. H. H. Putnam, vice-president and general manager, Birmingham Waterworks Company.

"Taste and Odor Problems," by Fred W. Thomas, sanitary engineer, TVA, Wilson Dam.

The afternoon session for the sewage section was a period of classroom instruction on chemical tests, under the direction of M. C. Clear, sanitary chemist, Alabama State Health Department, Montgomery.

Papers presented during the morning of June 9 included:

"Public Relations," by Fred Scott, Jr., superintendent of water, Leeds.

"Small Sewage Treatment Plants," by C. E. Drummond, Jr., engineer, Wiedeman and Singleton, Atlanta.

"Testing Capacity of Wells and Selecting Pumps," by Glenn W. Cowham, superintendent of water plant, Montgomery.

"Stream Sanitation Program in Alabama," by J. C. Clark, assistant sanitary engineer, Alabama State Health Department, Montgomery.

Following luncheon an inspection trip was made to the Opelika water and sewage treatment plants.

At the Annual Banquet on June 9, the principal speaker was Ed Reid, executive secretary, League of Municipalities. Professor J. M. Faircloth, head, department of Civil Engineering, University of Alabama, was master of ceremonies.

The morning of June 10 was occupied by classroom instruction for both water and sewage sections.

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MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Arizona Sewage and Water Works Association	Pioneer Hotel Tucson, Ariz.	Nov. 30–Dec. 2, 1950
Texas Water and Sewage Works Association	Texas A. & M., College Station, Tex.	March 11–15, 1951
Virginia Industrial Wastes and Sewage Works Association	Hotel Chamberlin, Old Point Comfort, Va.	April 5–6, 1951
Arkansas Water and Sewage Conference	Hot Springs, Ark.	April 9–11, 1951
Kansas Sewage Works Association	Lamer Hotel, Hays, Kans.	April 11–13, 1951
Montana Sewage Works Association	Hotel Placer, Helena, Mont.	April 19, 1951
California Sewage Works Association	Hotel Californian, Fresno, Calif.	April 25–28, 1951
Michigan Sewage and Industrial Wastes Association	Hotel Pantlind, Grand Rapids, Mich.	June 4–6, 1951
Federation of Sewage and Industrial Wastes Associations	**Municipal Auditorium, St. Paul, Minn.**	**October 8–11, 1951**

Reviews and Abstracts*

Report of the Massachusetts Department of Public Health Relative to an Investigation and Study of the Causes Creating a Nuisance on the Shore and Beaches of Marblehead, Salem, Danvers, Beverly and Manchester and of Means of Rectifying Such Conditions. Mass. House Doc. No. 2,236, 14 pp. (Dec. 1949).

This report studies an area with a shore line of about 44.5 miles, in the vicinity of Salem, Danvers, Beverly, and Manchester. The various municipalities have a resident population of about 100,000, which is increased by 12,000 summer residents. About 14 m.g.d. of sewage are discharged into the waters by Marblehead, Manchester, and the South Essex Sewerage District. The latter contributes about 90 per cent of the total. Float tests indicated the movement of sleek areas. Over 260 private sewer outlets were noted.

The beaches were inspected after the close of the bathing season. Decaying organic matter was found, including garbage. The bacterial tests indicated the beaches were safe at the time examined. Further field investigation and enforcement of the rules and regulations of the Department, prohibiting pollution of inland and tidal waters were recommended.

LANGDON PEARSE

Report of the Sudbury Valley Commission Relative to the Sudbury River and Its Environs. Mass. House Doc. No. 2,351, 142 pp. (Mar. 10, 1950).

This is the report of four state officials on the sanitary conditions in the Sudbury River Valley, with a total land area of 257,327 acres (402 sq. mi.), containing two cities and 34 towns, as well as water areas and extensive meadows and swamps. Proposals for action are reduction of floods, control of low-water flow by reservoirs, removal of pollution, reduction of mosquitoes, and restoration of recreational use. The population in the area is estimated at 171,594 as of Jan. 1, 1950. Within 15 miles of the river is found a population of 1,662,755.

The river is controlled by a number of dams, as well as by abandoned reservoirs formerly used by Boston for a source of water. Weed growths, principally duck weed and water chestnut, are prevalent at low-water flow, stimulated by nitrates from sewage filtration plant effluents. At low water there is a flow of 1.5 m.g.d., to which is added 2.6 m.g.d. of effluent from two sewage works.

The pollution is substantially from the sewage treatment works effluents of Framingham and Natick, and the industrial waste of a carpet mill at Saxonville. Marked pollution has occurred in the Sudbury River, killing fish. If both towns and the industry discharge to the South Metropolitan sewer, the Sudbury River will be suitable for recreation, including bathing. The Assabet River is more industrialized and affects the Concord River. Vigorous pollution control is required.

The river flow is used for generating power and for processing purposes, also for irrigation of crops. Ponding has benefitted fishing.

Control of the land use by zoning is now mostly local, but should be extended on a broader basis. Fire control to prevent bog fires in dry seasons is also needed. Along with the dominant use for residence, provision for recreation is most important, to promote bathing, fishing, boating, and hunting, as well as stimulate wild life. Adequate and uniform regulation of the

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publications of public health departments, stream pollution control agencies, research organizations, and education institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

water area of the river and its banks is required. Farming is the most important commercial use. Some humus beds are also available.

The report also contains 20 supplemental statements—(a) Historical, (b) Legislative, (c) Hydraulic Data, (d) Sanitary Conditions of Rivers, (e) River Problems, (f) *Lemna minor* as an Aggressive Weed, (g) Mosquito Control, etc. Under "Sanitary Conditions of Rivers," the water supplies in the area are discussed, together with the disposal of sewage on the Sudbury River at six towns and one city, all served by separate systems of sewers. In three cases, the original intermittent sand filters have been superseded by Imhoff tanks and trickling filters. On the Assabet River there are sand filters at two towns and two state institutions; one town has Imhoff tanks and trickling filters. On the Concord River, Concord has an intermittent sand filter (effluent B.O.D. 1 p.p.m.). Industrial wastes entering these rivers are generally from wool scouring and finishing woolen cloth. The condition of the rivers in certain localities is unsatisfactory in extreme conditions. The Sudbury River at times is covered with heavy growths of duck weed, which decays and creates an odor nuisance. The water is unsuitable for certain industries at such time. The content of *B. coli* is too high for safe bathing. The Assabet and Concord Rivers are unsafe for bathing and the Concord River is unsuitable for industry.

The population equivalent tributary to the sewage works on the entire watershed is 77,350. The effluent is equivalent to 6,375 persons. If the Framingham and Natick sewage effluents were diverted, the effluent equivalent population would be reduced to 3,035.

The conclusion is that a minimum flow of 4.1 m.g.d. should be maintained in the Sudbury River below Saxonville by utilizing available storage, after diversion of the Natick and Framingham sewage.

The prevalence of duck weed in the Sudbury and the Charles Rivers is discussed and the conclusion is reached that alkaline sewage wastes have an important bearing on the weedy behavior of *Lemna minor* in both rivers.

(Comment by abstractor—This well-balanced report, covering an area of 400 sq. mi., is worthy of study by those interested in water pollution control.)

LANGDON PEARSE

Ducks and Shellfish Sanitation. By MILTON H. BIDWELL AND CORNELIUS B. KELLY, JR. *Am. Jour. Pub. Health*, **40**, 8, 923 (Aug., 1950).

In the past 12 years a number of shellfish sanitation studies have been made in the Peconic River area at the eastern end of Long Island, where pollution of human origin is insignificant but pollution from duck farms is very great. Samples of duck farm overflow have had suspended solids concentrations from 80 to 1,800 p.p.m. and B.O.D. values from 60 to 380 p.p.m. Coliform organisms are present in the order of 10,000,000 or more per 100 ml. During the peak summer season, the estimated domestic sewage population equivalent of the duck wastes is about 20,000 persons.

Bacteriological studies demonstrated that pathogenic organisms of the *Salmonella* groups (which include paratyphoid bacilli) were present in the duck farm wastes, in the oyster grounds, and in the shellfish. Therefore, agencies charged with shellfish sanitation must consider areas polluted by duck farms unsatisfactory for shellfish.

Abatement of duck farm pollution by plain sedimentation and chlorination was indicated by field and laboratory experiments. Detention for 1 hr. produced 50 to 93 per cent reduction of suspended solids. Application of 10 p.p.m. of chlorine to the settled waste in one experiment reduced the coliform index from 46,000,000 to 430 with a residual of 0.7 p.p.m. of chlorine after 15-min. contact.

M. R. GOLLY

Difficult Waste Disposal Problem Solved. By K. M. BROWN AND S. KURTIS. *Petr. Ref.*, **29**, 111 (Aug. 1950).

Spent caustic soda solutions are the most obnoxious wastes a petroleum refiner has to contend with. Almost all contain both phenolics and sulfides, making them directly toxic to fish, and their oxygen demand is very high.

The use of carbon dioxide from stack gases to neutralize spent caustic has not generally been practiced by refiners be-

cause of compressor corrosion problems. The gas cannot be compressed while hot; when cooled it contains sulfurous acid, which is highly corrosive. Improved catalytic cracking, however, provides a source of flue gas at 15 to 20 p.s.i. The gas averages 10 to 12 per cent CO_2, 5 to 6 per cent CO, and 1.5 per cent O_2, with nitrogen and inerts making up the balance, and has a temperature of 450° to 500° F, at the point of use.

Spent caustic liquor is fed from storage to the top of a tower containing 10 perforated contact pans, and flue gas is introduced at the bottom. The flue gas leaving the tower passes into a horizontal disengaging drum through a distributor, which provides additional contact with the liquor from the bottom of the tower. After a batch of caustic (1,700 to 2,000 gal.) is charged to the plant it is recirculated from the bottom to the top of the tower, by way of the disengaging drum, until neutralization is complete. The gas from the drum goes to a firebox, where hydrogen sulfide, mercaptans, phenols, and other components are burned. The liquor is pumped to storage and discharged to a sewer. Three to four batches can be neutralized per day.

Several operating difficulties were experienced. Spent caustic from kerosene sweetening contains naphthenic acids, which cause severe foaming; Dow-Corning Anti-foam A at 50 p.p.m. was very effective in controlling this condition. When caustic solutions from gasoline cracking contained about 40 per cent acid oils, the oils accumulated as a separate phase; when adequately diluted the oils were stripped out by the flue gas. The gravity of the charge must be kept below about 10° to 12° Baumé to avoid formation of carbonate and bicarbonate crystals.

Where refiners do not have catalytic cracking units, it appears feasible to use induced draft fans to force the gas through the neutralizer.

RICHARD D. HOAK

Economics of Sewage Disposal in Connection with Agricultural Utilization. By JAN WIERZBICKI. *Gaz, Woda i Tech. Sanit.* (Polish), **24**, 193 (May, 1950).

The author presents some data on sewage loadings (data for 1905 or earlier): Leicester, 25; Wrocław, 200; Paris, 206; Dortmund, 130; and Brunswick, 132 persons per acre. With the growth of cities and the discharge of industrial wastes, sewage farming as a means of sewage disposal became unsatisfactory. A historical review of the sewage farms in England is given, followed by a discussion of the developments leading to the distribution of sewage on irrigation fields and factors affecting their cost of operation. Some of the factors noted are distance from city to sewage farm, pumping requirements, leasing of fields to farmers, and operating personnel requirements. Wastes from small towns are reported to contain more fertilizing elements and are more suitable than wastes from larger cities, which may contain industrial and other toxic wastes. Winter, frozen ground, swamps, and rainfall all tend to reduce the amount of sewage that can be placed on the fields. As compared with biological sewage treatment processes, which are costly, sewage farming requires only simple pretreatment. In properly operated sewage farms, as a result of agricultural utilization of the sewage, the yields of hay increased five-fold and sometimes even eight-fold. Increases in other crops are also reported.

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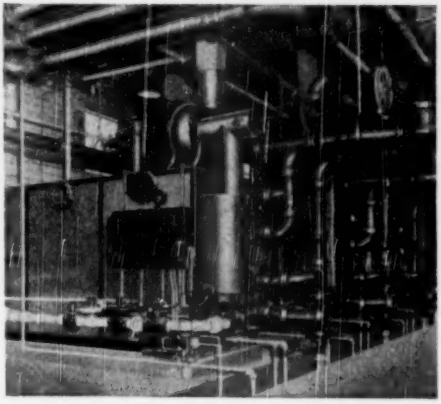

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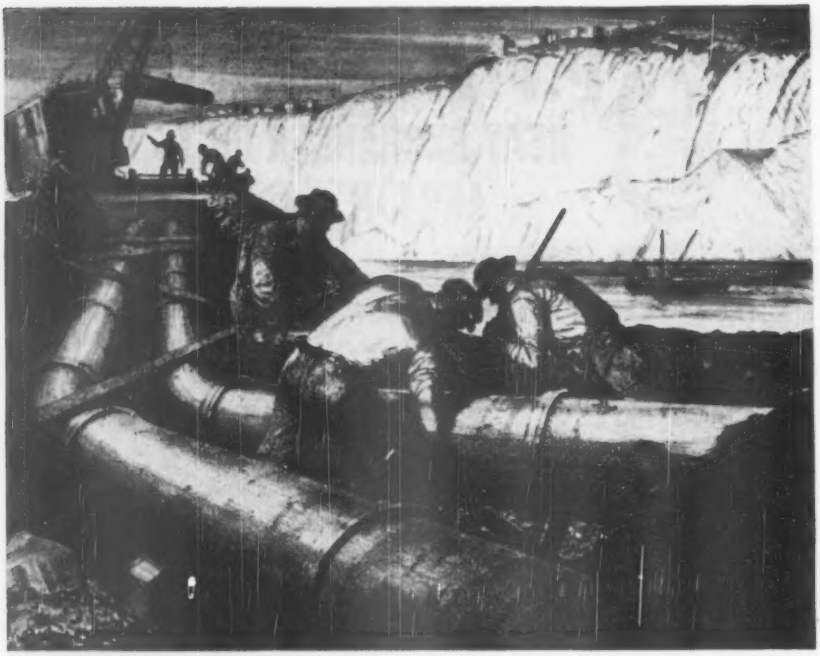

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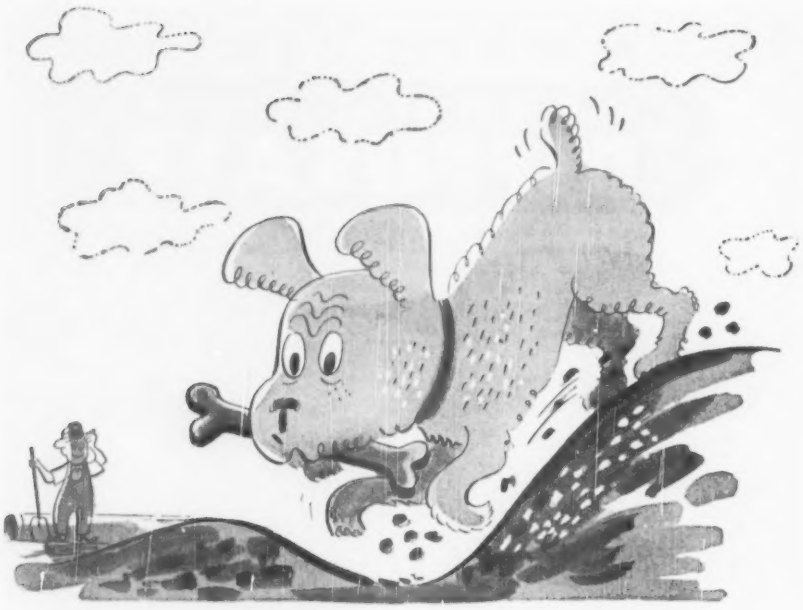

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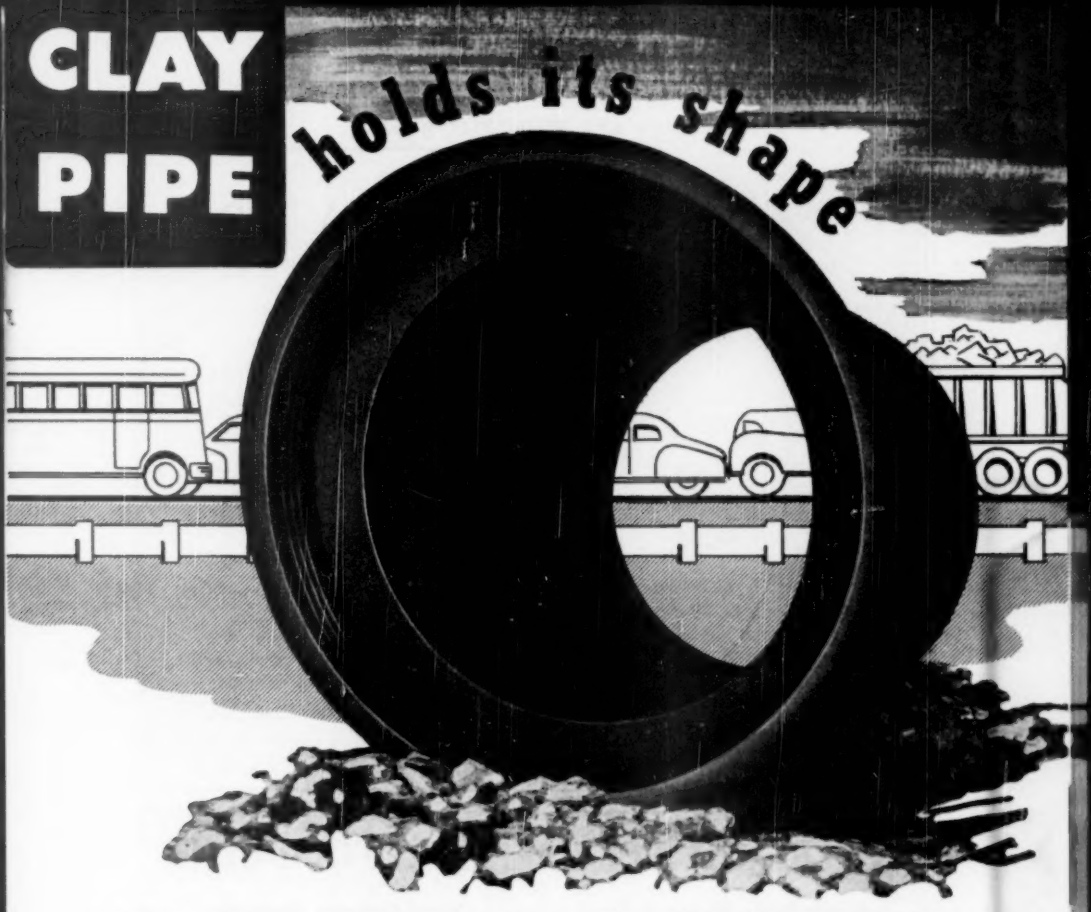

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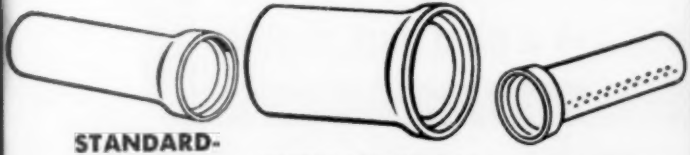

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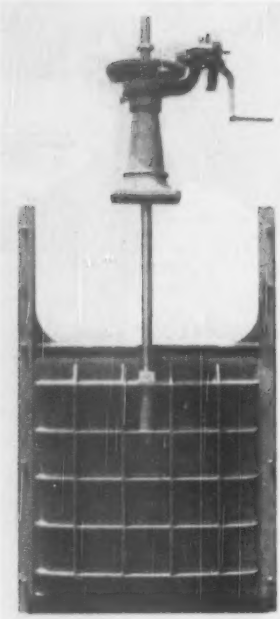

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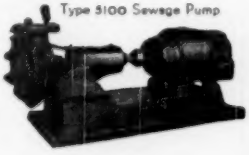
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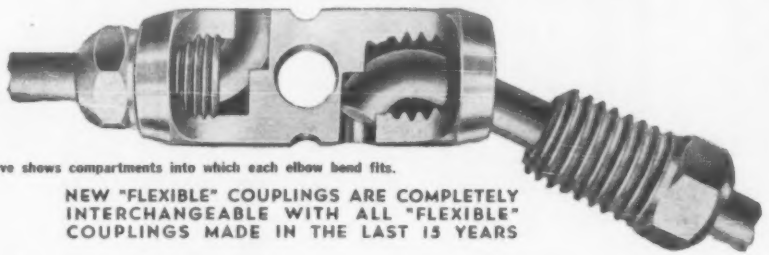

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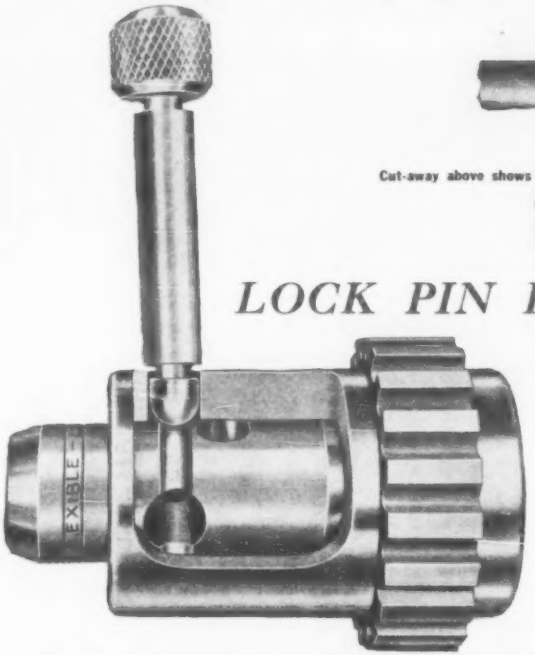

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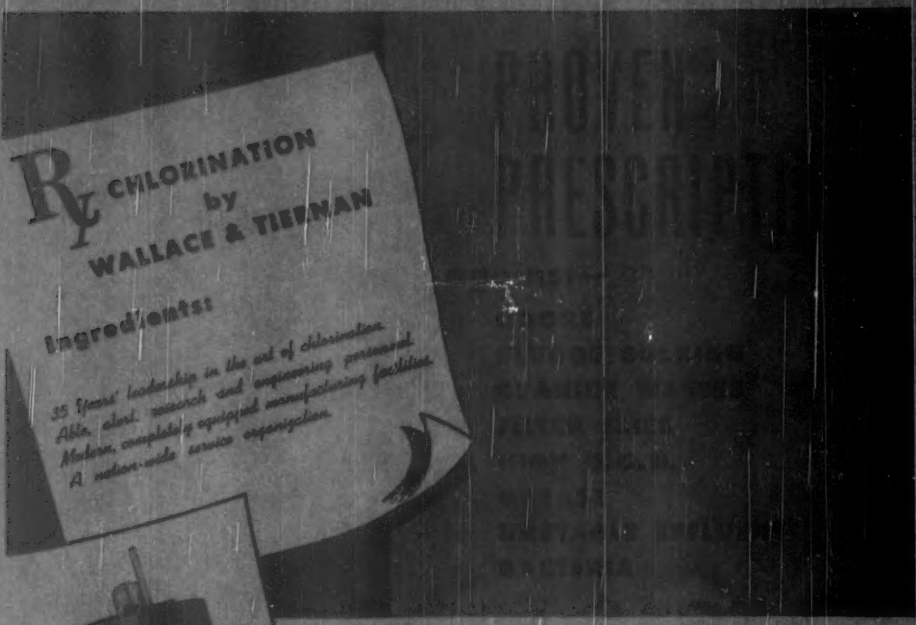

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